SILICON CHIP

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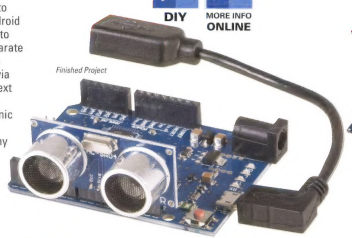

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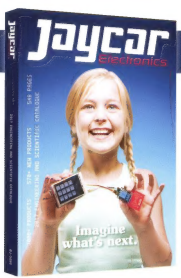

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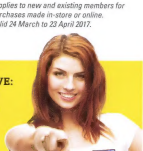

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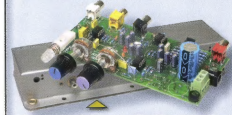

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Publisher's Letter

Big Brother can control your aircon

Australians love air-conditioning. Over the last few years, more and more domestic aircons have been installed, to the point where market penetration is now approaching 70% or more in some cities. And why not, Australia has hot summers and if people want and can afford air-conditioning, then there is no particular reason why they shouldn't have it.

In fact, most Australian cities have just sweltered through a very hot Summer and it can be particularly difficult to get to sleep on hot, humid nights. As someone who does not have air-conditioning at home, I can testify to that. That has made me consider having air-conditioning installed so that we can be more comfortable next summer.

But in thinking along these lines, I and millions of other Australians are contributing to an ever-increasing peak demand for electricity in those very hot summer periods and our diminishing grid cannot cope, especially with the trend to renewable energy sources which often do not contribute when they are most needed. For example, if a large high pressure system is stationary over the southern states, as can happen in the hottest summer weeks, there may be very little wind power generation. And solar panels drop their power output just when the evening peak demand is ramping up.

Ultimately, if there is insufficient grid capacity, the AEMO (Australian Energy Market Operator) can demand load shedding which means that consumers get blackouts. Great. So there you are, enjoying your hard-earned air-conditioning and all the other benefits of a modern economy and the electricity goes off and you don't know how long the blackout might last. This is set to happen much more frequently in South Australia but other states will not be immune.

In their "wisdom", the authorities have come up with another scheme to control peak domestic demand and it is called, ironically, a DRED or Demand Response Enable Device. It is a system to switch off or reduce the output of your aircon and is described in this month's issue by Dr David Maddison.

DRED-compatible aircons can have three Demand Response Modes, referred to as DRM1, DRM2 & DRM3. DRM1 completely switches off the compressor while leaving the fan running so without warning you will be left sweltering and wondering if your aircon has failed. DRM2 and DRM3 are modes which reduce the compressor's output and depending on how hot it is outside, you may not notice much change.

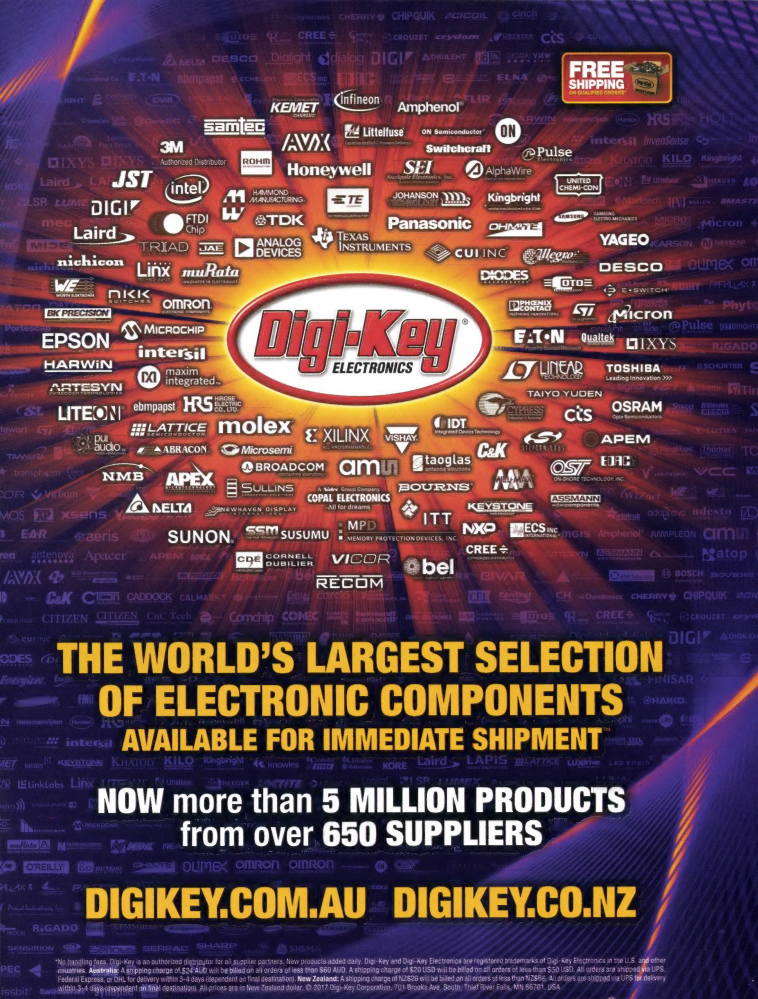
Virtually all aircons now being sold in Australia are DRM-compatible but most will require an additional module to be installed by the electricity retailer to enable it to be controllable. Some energy retailers are actively encouraging consumers to opt-in to DRED schemes with non-threatening slogans such as CoolSaver or PeakSmart and with one-off incentive payments.

But don't opt in; not if you know what's good for you! The incentive payment (typically a maximum of $400) is simply inadequate. It means that when you really want air-conditioning, it could be switched off. Worse still, if you have a grid-connected solar panel system, you could be subjected to the bitter irony of having your solar panels feeding the grid with power while you are deprived of air-conditioning. How happy would you be?

Right now, DRED is not compulsory but if Australia's grid becomes more crippled by having to accept more renewable energy input at the expense of good old reliable coal-fired base load power stations, you can bet that DRED will become compulsory for everyone who owns a compatible aircon.

Mind you, some technically savvy consumers might then decide to take matters into their own hands and figure out a way to disable DRED. Who could blame them?

Leo Simpson



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Model railway control for kids and beginners

Regarding the request for a low-voltage train controller for kids in the Ask SILICON CHIP section of the February 2017 issue (page 99), I have built two very successful AC Controllers for members of the Redlands Model Railway Group (RMRG). These use a KEMO Low Voltage AC Controller: http://siliconchip.com.au/l/aacm

If you use a transformer with say 9VAC and 18VAC taps, you can switch between low and high speed to give more control. Note that the actual voltage selection will depend on the AC locomotive used.

I used one pole of a centre-off switch to select the 9V or 18V tap while the other pole modified the speed control resistance to give the best speed control range over the sweep of the potentiometer.

I did not notice any issues due to the phase angle control of the AC dimmer module. I suggest using a small circuit breaker to protect against track shorts due to derailments.

Secondly, regarding the letter titled "12V speed/dimmer control modification" on the same page, RMRG has a "U Drive" layout (as they call it). I found the solution for controlling such a layout was to use a PWM controller (such as the KitStop unit) and vary its DC supply voltage.

The benefit of doing this is you still have the full PWM control range but limit the top speed. The other advantage is you can easily adjust the voltage for different locos.

I used the Altronics K6340 1.5A adjustable power supply, which is more than enough for this application: www.altronics.com.au/p/k6340-mini-switching-regulator/

I also added an adjustable timer, so for a gold coin donation, they could have (say) five minutes of running time.

Mike Abrams,
Capalaba, Qld.

Leo Simpson comments: Your email raises a number of points.

If you use a dimmer with a bridge rectifier to drive a DC motor, it suggests that the switching device in the KEMO controller is probably a Mosfet rather than a Triac; otherwise the Triac would have commutation problems.

Using a low-voltage dimmer in this way does give you a simple controller but you do not have the facilities of braking or inertia that can be incorporated in a conventional design such as the Stationmaster which we just published.

As to your idea of adjusting the DC supply into the PWM controller, that actually reduces one of the real benefits of PWM design, that of having a high peak voltage to overcome track contact resistance. It does preserve the full range of duty cycle as you say but in practice, that should not be a problem if you have a fixed DC supply and set the maximum duty cycle (and thereby full speed) to suit a particular locomotive.

Pool Lap Counter circuit diagram error

I read with interest the drive arrangement for the display for the Pool Lap Counter in the March 2017 issue. I was wondering when it would fail, looking at the circuit of Q3 & Q4.

Then I read the description of its operation, and 1kΩ resistors are mentioned, and also shown in the parts list. They are also shown on the PCB. However, they are missing from the circuit diagram.

Henry Wyatt,
Carindale, Qld.

Comment: Well spotted, Henry. If the circuit was built that way, Q4 and Q6 could potentially self-destruct when their respective RA3 and RA4 control lines from IC1 went high.

Fortunately, as you point out, there are 1kΩ limiting resistors in series with the bases of Q4 and also Q6 on the PCB so that event won't happen.

We have published Errata on this point on page 96 of this issue and we have also corrected the circuit on page 26 of the on-line issue for March 2017.

Neutralisation is positive feedback

I have some comments regarding the March 2017 issue, so please accept them in the spirit in which they are given.

In the Publisher's Letter, you say that neutralisation is positive feedback; I could've sworn that it was negative feedback to prevent oscillation involving the plate and the grid (hence the screen grid), so where have I been led astray?

The Pool Lap Counter appears to protrude a centimetre or so from the wall. Wouldn't that upset some of the more competitive swimmers?

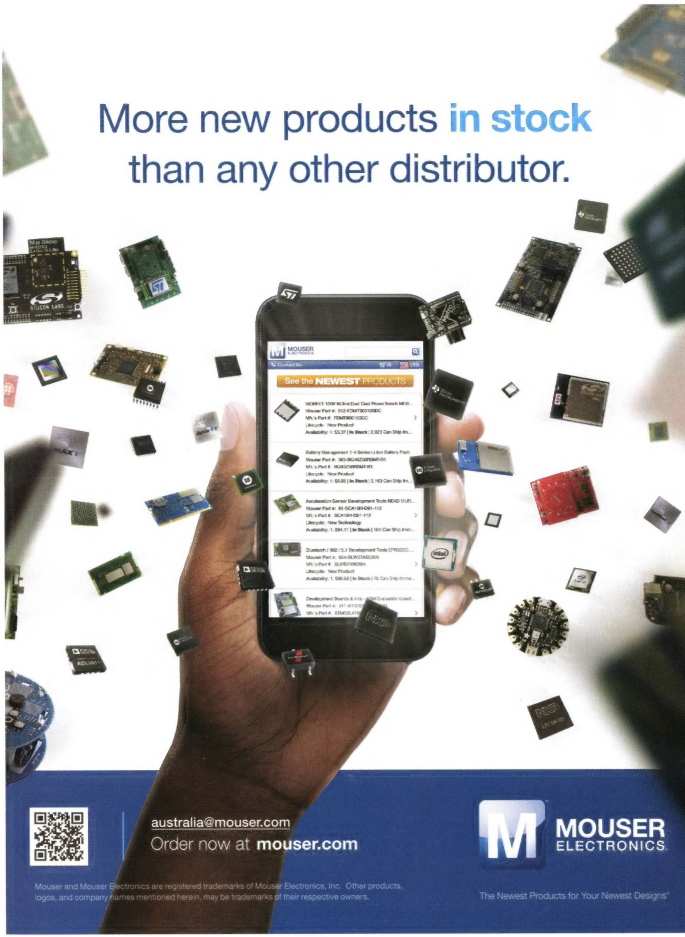
In the Stationmaster article, I am quite taken by the reference to the 10kΩ capacitor (in the second, paragraph, third column, page 37) – that's one hell of an ESR!

D. H, by email.

Comment by Leo Simpson: Another reader made the same comment and he thought that I might have had a "seniors' moment" and that I should have been referring to the term regeneration. However, neutralisation is definitely positive feedback and it counteracts the frequency losses in valve and transistor RF stages, due to Miller Effect (inter-electrode capacitance causing negative feedback).

Have a look at http://siliconchip.com.au/l/aacn

I don't think too many competitive swimmers would be worried about the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Mailbag: continued

Drivers should be made aware of airbag dangers

I liked the Publisher's Letter in the February 2017 issue, on car drivers' and passengers' nonchalant approach to airbags.

I was trained in the "10 to 2" position for my hands on the steering wheel (sometimes I go to quarter to three or even with one hand at the "6 o'clock" position if the road is very straight) long before airbags or power steering.

The thought of being hit/kicked in the face with one's own appendages has often caused me to wince, when I have observed a passenger with their feet over the passenger airbag compartment.

Perhaps part of the 120 hours of driver training should include identification of such dangers and be the requirement for the driver in control of the vehicle to maintain passenger safety (irrespective of the passenger's age!).

Ray Smith,
Hoppers Crossing, Vic.

thickness of the touch plate for the Pool Lap Counter. After all, it is not a timer; it is only counting laps.

The 10kΩ capacitor is actually a resistor, as you probably guessed. It's very annoying that we didn't spot that ourselves though!

Serviceman's snoring solution isn't unique

The Serviceman's article in the February 2017 issue was most interesting. It is certainly the result of an active and inquiring mind. It reminded me of talk floating around during my army days many years ago.

The less-than-subtle military approach to snoring amongst SAS personnel was apparently very effective. This consisted of inserting a diathermy probe down the nasal passages to burn part of the flappy bits that caused snoring. Apparently, when healed, the resultant scars toughened up the area, preventing snoring.

I believe it was a voluntary procedure, apart from any pressure applied by fellow soldiers, due to concerns about security and detection when in the field. Recently, I obtained a device similar in concept to the serviceman's project (my wife claims I snore but I am unaware of it).

This device, they claim, "is designed to interrupt snoring without waking up the snorer or their partner". A microphone detects snoring and it then activates a silent air pump, that in turn inflates a pillow insert. This movement interrupts the snoring. This is just a tad more subtle than being prodded, or hearing "tender loving endearments" from a sleep-deprived partner.

I don't know if they are in full production as mine was a pre-production job from a start-up company. You may want to check it out or review it. It's called "Smart Nora" and is at www.smartnora.com; I have no connection with the company, other than being a customer.

Robert Malone,
Greenbank, Qld.

On frank discussions, renewable energy and alternators

For a while, a number of letters have been published in SILICON CHIP in which the authors complain of the publication of personal views on subjects which are not purely electronic. Why? Although SILICON CHIP is predominately electronics-based, I have noticed that SILICON CHIP magazines have not stated on the front cover that the magazine is an electronics magazine since about 2003.

Also, if Leo Simpson is biased, so what? We all are. Haven't those who complain noticed that letters both critical and supportive are published?

Readers may have noticed that I have had a large number of letters published on various subjects. However, I have also had a large number rejected and some of those I considered excellent commentary. C'est la vie. I am just so glad that SILICON CHIP does not publish dribble grade stuff like that on social media.

These first two months of 2017 have been atrociously hot, or at least they seemed that way. A quick look through the temperature records showed that there have been worse periods but even so, the weather patterns in Queensland were unusual. The protagonists of global warming and climate change would not hesitate to blame CO_2 and fossil fuels but would they be correct?

Solar panels and wind power generators are stated as being environmentally friendly but is that totally true? Aside from the detrimental effects of their manufacture, solar panels and wind generators modify the environment into which they are installed.

If the energy generated by solar panels is used immediately at the location of the panels, then there should be no net loss or gain of heat by the environment compared to that without the panels.

If, however, the energy is stored or transported to another place, then the panel location will be cooler than if the panels were not there and the location where the energy is used will be warmer. The environment has been impacted and the micro-climate has been changed. Perhaps the weather has been changed as well.

Wind power generators are no different and are probably worse than solar panels, mainly because they are so much larger. Aesthetics and noise are of no real concern. They are personal dislikes. But air flow is a different matter. The inclusion of wind power generators into the flow of air causes a loss of kinetic energy which equates to a loss in the speed of the air flow.

A person would need to be in total denial not to realise that the environment has been impacted downstream of the wind turbines. Obviously, with a large number of wind power generators, the impact must be appreciable.

Weather systems are treated as chaotic systems and one of the behaviours is that a small disturbance can have a major effect at a later time.

Consequently, it is quite possible that both NSW and Queensland have been inadvertently subjected to a hotter summer than normal either directly or as a flow-on effect of other weather patterns being changed. Certainly, there were none of the cool winds that normally came from South Australia.

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Mailbag: continued

Water tank level monitoring with Raspberry Pi

In the February 2017 issue of SILICON CHIP, in the Ask SILICON CHIP section, there was a question regarding connecting your water tank gauge to the Raspberry Pi.

The answer suggested connecting a 5V level to the Raspberry Pi GPIO inputs. The Broadcom SOC on the Raspberry Pi operates on 3.3V logic levels. My understanding is that a GPIO pin should never be connected to a voltage source greater than 3.3V or less than 0V, as damage to the chip may occur.

You would also need to consider how much current the GPIO pins are sinking. For sink current, the limitation is based on maximum chip power dissipation.

Once again my understanding is that you can safely sink up to 16mA each into any number of GPIO pins simultaneously. Given you were driving LEDs this should be OK but would be worth checking. Note sourcing current limitations are different to sinking.

It would probably be easier to connect an ultrasonic sensor directly to the Pi (via a voltage divider, since they are mostly 5V devices as well). This article provides a good overview on how to do this: https://electrosome.com/hc-sr04-ultrasonic-sensor-raspberry-pi/

Great magazine, by the way – some more articles on the Raspberry Pi would be nice!

David Such,
Woronora, NSW.

Editor's note: the Ultrasonic Water Tank Level Gauge has 470Ω current-limiting resistors connected to each of the output pins mentioned last month. If the connections to the Raspberry Pi were made to the end of these resistors which connect to the LED cathodes, those resistors should limit the current in to the Rpi's input clamp diodes to around 3mA, which ought to be safe.

A higher value, such as 4.7kΩ would be even better. Ideally, the LEDs should be removed (or not fitted) since it would be difficult to arrange for the Gauge's 5V rail to always switch on after the RPi's 3.3V rail and switch off before the RPi.

On another topic, I have a neighbour who works as a car technician and occasionally he gives me dead automotive alternators in which either the regulator has failed, or the run-on clutch has failed.

These things normally have a rated output of near 1kW but now I have one of 2kW and one of 2.5kW. To quote the labels, they can generate 140A @ 14V and 180A @ 14V respectively. Obviously, there is a need for a lot of electrical power in modern vehicles. No wonder there has been a push for higher voltages (ie, 42V systems).

George Ramsay,
Holland Park, Qld.

Automotive electronic environment is harsh

In the Ask SILICON CHIP pages of the February 2017 issue, G. G. from Paringa sought advice on protecting a 555 (16V maximum supply voltage) in a 12V automotive environment.

While catering for a ~15V charging voltage and short high-voltage transients is sufficient for normal operation, if the battery ever becomes disconnected while charging, the resulting "Load Dump" may rise to 100V and take 400ms to decay.

Careful selection of the series resistor and zener power ratings can add load dump protection where the load is modest, as in a 555 circuit. Where the normal load current is a bit higher, an emitter (or source) follower on the zener is more efficient.

Other surprising voltages can lurk under a car bonnet. When the first LED clock prototypes were trialled in the XD Falcon, in the final stages of its development and testing, the Ford staff reported that "The clock works fine at first, but dies the second time it is turned on."

An unscheduled trip to the You Yangs proving ground, equipped with storage oscilloscope, polaroid camera and several layers of management, was rapidly organised.

It quickly became evident that when the ignition switch was turned off, a -1000V spike was generated on the accessories line, which was used to turn on the display. When we asked what was wrong with their flywheel diodes on the accessories relays, the reply was "What are you talking about? The clock will have to take it."

After everyone had gone home at the end of the day, one junior engineer sat with the challenge; the fix wasn't allowed to cost anything. Fortunately, significantly increasing the value of the series resistor on the CMOS input allowed the device's input clamp diodes to deal with -83 times nominal input voltage, year in, year out. A simple lesson in real-world electronics I've not forgotten, even after nearly 40 years.

Erik Christiansen,
via email.

FM antenna mounting greatly affects reception

As an avid listener to ABC Classic FM for 40 years, I have set up a suitable FM antenna system each time we moved house; a task made somewhat easier because of my experience (in younger days) as a TV antenna installer.

We lived in suburban Perth for a while, where I enjoyed the ease and luxury of digital radio (good reception even in a tin shed on the wrong side of a hill!) but recently we shifted to a small coastal town in south-west WA, so no more digital radio – back to FM.

My faithful little ¼-wave Yagi, which had performed so well in other settings, didn't seem to be pulling in much FM signal. This was rather mystifying because we are only about 65km from the tall (~300m) and powerful (100kW) Bunbury transmitter, with quite flat terrain in between.

The digital TV signal from the same tower was picture perfect using a small UHF antenna mounted on the same 1m mast. So why was the FM signal so bad? The ABC's reception advice website said I was in an "adequate reception" area; the situation was inexplicable and annoying.

Eventually, the poor reception compelled me to research the situation

further and I discovered that the local Bunbury transmission tower used vertical polarisation for FM, making it one of only a few high-power vertically-polarised FM transmitters in Australia; Renmark in Victoria is another.

Most FM transmitters nowadays use either horizontal or mixed polarisation, with vertical mainly used by low-power local repeaters in remote areas.

Anyhow, I remounted my little Yagi on the vertical (ignoring for the moment what the metal mast and the nearby UHF TV antenna would be doing to things) and bingo – instantly better reception, although it is still prone to some fading and white noise in the afternoon and during adverse weather.

So I invested in a proper 3-element Yagi, about 1.8m tall at the rear reflector. This was quite cheap at about $45, although it cost nearly that much again in freight.

The new antenna would not fit on my existing mast because of the vertical orientation so I needed to put up a taller pole on top of the roof.

I pondered the problem of how to vertically mount my new Yagi, either directly on a mast (cheap metal pipe) and suffer the inevitably reduced performance caused by having the metal pole in the middle of the antenna in the same (vertical) plane as the elements. Or offset-mount it on a long horizontal extension hanging off the top of the mast (ugly and prone to wind damage), or use a fibreglass mast.

A suitable non-conductive mast was available for less than $50 but as with the new Yagi, freight would double that.

But then I found a fibreglass painting roller extension pole costing less than $40, in a local hardware store. The hollow yellow fibreglass section of this was about 32mm diameter and almost 1.9m long and quite strong enough to support the new antenna. Fixing this mast in place was relatively easy although grubbing about inside the roof lacked the appeal it had when I was forty years younger.

That only left the problem of the coax feed from the antenna. There isn't much point in using a fibreglass mast and then running coax down that mast, as the coax shield could detune and defocus the Yagi too. So I used UV-stable Nylon rope as a support line and ran the coax from the antenna at a shallow angle to the horizontal (but at right angles to the axis of the Yagi) to another part of the roof and then down to my hifi systems.

The result is great! The ubiquitous white noise and mid-afternoon fade are gone and I can supply three radios without using a distribution amp. As well as much better clarity, channel separation and virtually no hiss (except at insane volumes), there is a marked improvement in bass, taking me from "tinny old wireless" to near CD-quality.

I no longer need a graphic equaliser to massage the audio into something resembling fidelity and I've upgraded the lounge room speakers to capitalise on the improvement. For a moderate cost and effort, along with a little lateral (or is that vertical?) thinking, I'm back in audio heaven.

Lindsay Peters,
Broadwater, WA.

Technical decisions made for political reasons give bad results

Although I assume that Ian Patterson is in the minority group, he certainly has the right to express his opinion. But that should not be at the expense of general discussion.

As our political masters are becoming increasingly interventionist in their quest to seek votes in every nook and cranny, they have, albeit by default, essentially taken over the technical decision-making process from the various departments who should be accepting this role as a prime responsibility.

One harmful side effect of this transfer of responsibility can be seen in the increasing number of government decisions, particularly those related to all forms of infrastructure, that can only be described as bizarre.

With almost every commentator in all forms of the media espousing the party political line without any support of it by way of reasoned argument, it is refreshing to read an editorial that simply throws an idea into the ring and lets people kick it around.

Let there be no doubt that the current popular processes, driven by flawed business school thinking, are certainly taking us to our inevitable terminal end.

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Mailbag: continued

Model train PWM doesn't involve rapid polarity reversal

Probably someone else has already pointed out the small error in your Pool Lap Counter circuit. The text states that there should be 1kΩ resistors in the bases of Q4 and Q6 but these are not shown on the schematic, although they appear to be on the PCB layout.

In your article about the Stationmaster model train controller, I don't know if Bob Sherwood ever had anything to do with model trains but his comments on page 34 about being able to push a model locomotive along the track or have it roll down a steep grade are not correct. Most model locomotives are driven by a motor using a worm gear, almost always single-start, which means they are non-reversible.

You can certainly push a loco along the track, but with the wheels locked skidding on the rails, and for it to roll down a steep grade, the grade would have to be vertical. Very few model locos use spur gear drive, and even then the friction in the gear train would probably prevent them moving.

As for the design, it seems strange to use a method of speed control which involves switching rapidly between forward and reverse with a varying duty cycle. Many model locos now use can motors with low armature inertia, and I can imagine the dynamic forces on the motor and the heat possibly generated by effectively trying to reverse the motor 8000 times per second.

You have not shown any waveforms coming out of the actual H-bridge, but since the FETs switch rapidly, you are relying on the inertia of the motor to damp the reversals. I grant that very few motors will actually reverse 8000 times per second, but it still seems like placing an unnecessary load on the motor when you could just use a reversing switch, which would also simplify the circuit.

A. Danilov,
Naremburn, NSW.

Comment: Another reader has pointed out the error in the circuit of the Pool Lap Counter and Errata will be published in this issue. In addition, the online issue has been corrected.

You are right about most locos having worm drives – that should have been edited out.

However, in this case, the PWM control does not involve rapid reversal of polarity; it is pulsed. For travel in one direction, pulses of a single polarity are applied to the tracks, with varying widths depending on the desired speed.

For travel in the other direction, the polarity of the pulses are reversed but the pulses of one polarity always stop well before pulses of the other polarity start (even with the inertia control set at minimum).

There are some PWM circuits which rapidly switch pulse polarity as you have discussed but the Stationmaster is not one of them. Note that motor inductance normally limits the rate of change of current through the motor such that PWM drive does not actually cause such rapid changes in force.

You alone have to decide on the best form of content to ensure the continued success of SILICON CHIP in an era when technology is certainly not on the government favours list and technical magazines of all sorts have all but vanished. Keep up the good work and let the discussions proceed.

By the way, your feature on the passing of Maurice Findlay was very well presented. Dick Smith was not the only one he inspired, as we all know people who entered technology based careers and made huge contributions after having been guided to that decision by the writings of Maurice.

George McLeod,
Georges Hall, NSW.

ABC radio HF shortwave shutdown is bad news

I wholeheartedly agree with the Publisher's Letter in the December 2016 issue, stating that controversial topics should be able to be discussed! This seems an increasing growing issue that for fear of upsetting someone, minority groups or even an individual we must accept and not argue or put forward alternative suggestions/options or even just question the basis/science/motives of the original topic.

Isn't conversation and debate of issues and topics the basis of democracy after all? Perhaps it will result in the loss of some subscribers with knee-jerk reactions who cancel their subscription because they don't agree with everything they read.

But on the flipside it keeps the magazine relevant with current issues and when it's related to technology, it does the opposite for me in cementing the reason to keep my subscription.

SILICON CHIP has published a number of articles on topics I'm only loosely aware of and they have provided me knowledge and understanding to base my opinions on.

So I say keep up the good work on the magazine and don't ever become soft and politically correct by only printing "popular" and "safe" articles with the same "popular" and "safe" stances we hear day to day and over and over because that would cost in subscribers also. I doubt I'm the only one with this view.

Your editorial also struck a chord with me with regards to the recent ABC (Australian Broadcasting Corporation) decision of closure of the national/inland and overseas shortwave broadcasting services. ABC announced on 6th December 2016 that it will close/shutdown the shortwave services from 31st January 2017 in an effort to move away from "outdated technology" and use the cost savings to invest in digital transmission services and that "local" FM, satellite, streaming and AM/MW/MF services will fill the void.

I disagree with the ABC's view and think that their motives are more basic and sinister, as I will explain later. I also think that this will be detrimental to Pacific Islanders. The closure of the local/national shortwave services

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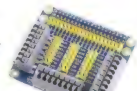

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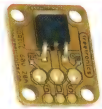

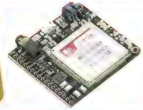

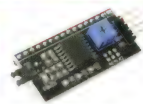

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in the Northern Territory also seems unlikely to provide improvement to Territorians' access to news and current affairs. I may be wrong but it should be up for discussion and review rather than just pushed though.

I should declare that I have a bias due to working at the Shepparton HF transmission site for the years of 2009-2015, being involved in operations and maintenance of the international broadcasting infrastructure and have family connections to the site for many more years than that. That said, there has been some backlash since the public announcement on local/national ABC radio services from Territorians about the lack of radio coverage and availability of the modern alternatives in the red centre of Australia.

There has also been backlash and concerns from areas in the Pacific as well, as they rely on this service in times of natural disasters as the local "more robust" FM services (as the ABC would call them) are often the first casualty in a severe weather event, with loss of power and/or broadcasting equipment damage.

Australians on the whole aren't very familiar with the international shortwave broadcasting of the ABC Radio Australia programmes and the privately owned infrastructure providing it at the Shepparton HF transmission site. If you haven't lived in the Northern Territory or been around broadcasting and amateur radio, you would also not be aware of the inland shortwave services and their purpose. That's expected and totally understandable as neither are a service provided for the majority of Australians.

The ABC would of course state that all proper consultation with affected parties and plans of the intended shutdowns was carried out. To this, I would say that's a lie and the main reasoning behind the shutdown is a fight/disagreement between the ABC and the elected Liberal government on funding.

Basically, it's always about the money. Tony Abbott's election victory in 2013 went to the polls with "no funding cuts to the ABC" and once elected, lo and behold, funding cuts to the ABC.

In early 2015, changes were made to the international broadcasting side in the reduction of shortwave transmission services on air, reduced from eight (six from the Shepparton HF transmission site and two from the Brandon MF transmission site in Queensland) to only three total shortwave services, all from Shepparton with a much reduced diversity frequency schedule, allowing reductions in transmission costs to the ABC.

I resigned from my position with Broadcast Australia and the Shepparton HF site soon after this with a mixture of personal reasons (which were influenced by the decisions at the time) and uncertainty of the future of shortwave transmission.

On 13th August 2016, I noticed that it was very quiet on the shortwave bands on the Radio Australia daytime frequencies when testing/restoring an old radio and sent the ABC feedback, knowing that it was unusual that no services were present. I hit the internet and asked family what they knew and had noted that it was off earlier during the week also. This seemed unusual at it was always the policy for fast and efficient service restoration at the Shepparton HF site and the site has redundancy with spare/backup infrastructure.

I received a reply a from the ABC on the 15th August that they were "currently working with our transmission provider on a number of shut-downs over the past week and again during this week to investigate a range of technical and commercial issues for the service. In the meantime the services are still on air via our satellite services on Intelsat IS18 and IS20 as well as our FM network across the targeted markets in the SW Pacific".

I had hoped for a better reply than what was obviously the company line. I investigated a little further myself and concluded that it was a trial to see how many complaints would occur. I was in disbelief but decided that this was a plausible scenario, although I doubt that it's in writing anywhere and hence would only be the word of a biased individual (myself).

My biggest issue with this process is the lack of consultation with the affected parties and justifications based on lies and poorly based technical arguments. Shortwave as full carrier amplitude modulated double sideband signal is an old transmission method but it's the same transmission signal type used with the AM/MF/MW broadcast band from 530kHz-1600kHz.

It seems unlikely that the ABC are going to shut down their transmissions on that band due to it being outdated in favour of FM/Digital services and platforms in the near future due to coverage and commercial limitations; radio is a cheap way to access mass markets compared to internet streaming and so on.

Really, it comes down to listeners' preferences in the end. People won't listen to what they don't want to, regardless of technology or transmission type and obviously can't if the coverage isn't available to them.

David Alford,
Shepparton, Vic.

Using Nora or maybe a smartphone to stop snoring

Have you head about Nora? See: www.digitaltrends.com/home/the-nora-is-a-smart-device-that-stops-snoring/

I was tempted to try something like that myself, using the pump from a cheap but inaccurate blood pressure wrist-cuff.

Alternatively, wouldn't it be possible to use a smartphone to stop snoring? With the phone placed under the pillow, it could run software to monitor sounds, filtering for snoring, then turn off the mic and play a tone upon detecting it. There are already free phone apps which listen and record snoring events. Dave, how are your phone programming skills?

I use a CPAP machine. I have "moderate" sleep apnoea (based on the results of a sleep study), but my main reason for using the device is to avoid divorce. It is effective, but uncomfortable, expensive and too bulky to take on motorbike trips. Maybe I should try Dave's solution?

Ken Wagnitz,
Craigburn Farm, SA.

Current convention should not be changed

Attempts to define the direction of an electric current as the direction of electron flow only leads to complications in an attempt to "simplify" the real issue – the old problem of over-simplification.

Early studies of static electricity revealed there were two different types of electric charge. One was assigned as positive and the other as negative.

In the early days of electricity and magnetism, investigators and practitioners did not really know what an electric current actually was. Arbitrarily, the direction of electric current was deemed to be from positive to negative.

Three "hand rules" were established to indicate the direction of a magnetic field around current carrying conductors, through solenoids as well as the direction of force experienced by a current carrying conductor in a magnetic field.

The direction of an induced current in a conductor moving through a magnetic field could also be determined.

The three hand rules are:

First – in your imagination, take the current carrying conductor in your right hand, thumb pointing in the direction of current (positive to negative), the natural curl of your fingers will give the direction (N to S) of the surrounding magnetic field.

Conversely, if you curl the fingers of your right hand around a solenoid in the direction of the current, your thumb will indicate the direction of the magnetic field within the solenoid.

Second – with your leFt hand ("F" for force) set your thumb and first finger at right angles to each other and in the plane of your palm, your second finger perpendicular to the plane of your hand.

With your First finger in the direction (N to S) of the magnetic field (F for field), your seCond finger (C for current) the direction of force on the conductor will be given by your thuMb (M for motion).

Third – with your rIght hand ("I" for induced current), set your thumb, first and second fingers as above. Again, First finger the magnetic field direction, your thuMb in the direction in which the conductor is moving through the magnetic field, your seCond finger will give the direction of the induced current.

These rules assisted the application of electromagnetism to motors, generators etc. They only apply to the direction of current in a conductor as from positive to negative.

Later, Thompson's investigations into currents through rarefied gasses and eventually a vacuum indicated the presence of positive and negative charges in the atom. (Canal rays and Cathode rays).

Eventually, the discovery of the electron lead to the realisation that an electric current in a metallic conductor is actually carried by electrons moving from negative to positive (opposite to previous concepts).

Now things become complicated and the overall decision was (in light of the well established "hand rules") to maintain the concept of current from positive to negative as a convention (dictionary definition: a convenient form).

Matters become even more complicated when considering electric currents through plasmas and during electrolysis of solutions.

Here the electric current is carried by both positive and negative charges moving in opposite directions. At this point we will leave out semiconductors and "holes", basically still an electron "flow".

So what is the real issue? An electric current is defined as "the passage of electric charge". The magnitude of the current is given as the time rate of transfer of charge. The direction of the current given as the direction of transfer of positive charge.

In fact, the definition of the ampere is the transfer of one coulomb of electric charge per second (the standard ampere is given in a different form that is easier to measure rather than trying to deal with an isolated electric charge of one coulomb).

My advice is to maintain the conventional current direction as positive to negative while realising (and hopefully understanding) that there are exceptions to the rule.

Col Hodgson,
Mount Elliot, NSW. SC

Just imagine if your electricity supplier could remotely turn off power to a heavy-use device such as your air conditioner, without your knowledge or perhaps even your approval. . . Imagine no more, because

DRED IS HERE!

DRED stands for Demand Response Enable Device. It's a system whereby energy suppliers can switch off or reduce the amount of power drawn by domestic air conditioners. Virtually every air conditioner sold today is a DRED and is said to be DRM-compatible.

With the ever increasing use of air conditioners, a growing population and a reduction in National Electricity Market generation capacity over the last five years, Australia's electrical grid simply cannot cope with the peak demands in summer. When that happens, it means rolling blackouts (they call it "load shedding") for many thousands of consumers in the affected cities.

An alternative way to shed load is to only turn off power to selected high power consumption appliances such as air conditioners, water heaters and pool pumps while leaving lower power consumption devices such as lights, televisions and computers unaffected.

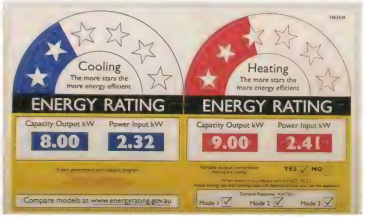
This concept is known as energy demand management (or demand management, demand-side management or demand-side response) and is implemented through a device known known in Australia as the Demand Response Enable Device with the very appropriate sounding acronym of DRED.

Energy demand management requires that appliances to be disconnected during a load shedding event have a special controller that can receive a signal from a utility company to turn them off or to reduce their power consumption.

The concept of energy demand management is not new in Australia or elsewhere but it used to be done for different reasons than insufficient power generation.

Electric hot water heaters and certain storage heaters (heat banks) used to be powered by "off peak" electricity which was much cheaper but only available at times (mostly at night) when power demand was low.

As well, electricity suppliers needed a way to sell their power so they could keep their coal-fired generators running at maximum power and efficiency continuously, since it is not feasible to shut them down.



When you buy an air conditioner in Australia or NZ you can see which demand response modes are supported from the energy rating label at lower-right – in this case, all three modes. So if connected, the supply authorities can throttle your air conditioner down, by 25%, 50% or to near-useless (fan only running, no compressor).

In Australia, the off-peak switches were originally connected to a time clock but in 1953 a (typically) Zellweger brand switching device was introduced to provide that function.

These work by responding to a "ripple signal" imposed on the transmission lines by the electricity retailer.

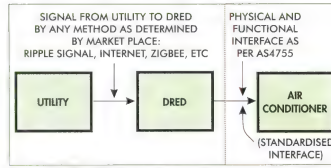
Obviously there would be a huge problem if an entire city's electric heaters came on at once so the various electricity retailers switch them at random times during during off peak periods.

Where smart meters are installed, these have a separate output, called "Controlled Off-Peak" which performs the same function to switch on the heating elements in hot-water storage tanks.

By Dr DAVID MADDISON

DRED FEATURE

Some manufacturers are making a feature out of DRED – but we wonder how many consumers will think it a positive feature when they're sweltering with a non-working, or only partly working, air conditioner?



Scheme for DRED showing how only the interface to the air conditioner or other device is standardised. The communications protocol and design of the DRED signal receiver is left to the marketplace.

Origins of DRED

The origins of DRED come from Commonwealth energy efficiency initiatives dating from 1992, which have since been managed by a number of different departments. These same initiatives are also responsible for mandatory energy efficiency ratings on various appliances.

In 2004, there were electricity supply problems which were blamed on excessive loads caused by air conditioning, so the Equipment Energy Efficiency (E3) Committee of Commonwealth, State, Territory and New Zealand officials was asked to examine the issue.

For many decades, supply authorities have been able to switch "off peak" hot water systems on and off with tone-control systems such as this Zellweger-Uster ripple control receiver. They superimpose a 1050Hz tone on the mains supply which is detected by this receiver to allow the hot water system to use cheaper, off-peak power.

They concluded that energy efficiency gains alone would not solve the problem and only "direct management of air conditioner operation during the peaks would be effective". Apparently, the option of allowing the marketplace to provide a sufficient amount of power generation to meet demand was not considered.

In 2005, Standards Australia set up a committee to look at the issue and published a standard. In its current version this standard is known as AS/NZS 4755.3.5:2016 "*Demand response capabilities and supporting technologies for electrical products – Interaction of demand response enabling devices and electrical products – Operational instructions and connections for grid-connected electrical energy storage (EES) systems*" and has also been expanded to include electrical storage systems such as batteries in homes and businesses.

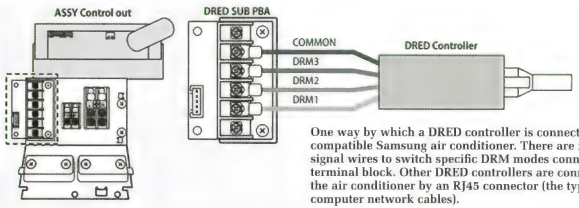
This standard is a world first for this type of technology and is under the auspices of the Australian Department of Climate Change and Energy Efficiency.

The aim of the standard is to provide an interface on selected appliances such as air conditioners that will allow remote demand management by the electricity suppliers during peak loads. This could be used on a hot day when the grid is running at maximum capacity due to the number of air conditioners in use. Users who are part of the program will have their devices shut down or reduced in their power settings in order that the grid is not overloaded.

Customers are typically provided with an incentive to install DRM-compatible air conditioners. Examples are Energex offering $100 to $400 for "PeakSmart" air conditioners, Ergon offering $150 to $500 and Ausgrid $150 to $400 for their "CoolSaver" program. A video on PeakSmart air conditioners can be seen at "*PeakSmart air-conditioning*" via **siliconchip.com.au/l/aace**

In accordance with the Australian Standard, conforming appliances must be able to enter certain "demand response modes" or DRMs. DRM1 is compulsory for air conditioners while DRM2 and DRM3 are optional. Most air conditioners now being sold in Australia are compatible with all three modes, which are as follows:

DRM1: The appliance is either shut down or running at a minimal load. In an air conditioner, the compressor would be turned off but the fan would continue to operate. Appliances that are only either off or on such as non-variable speed pool pumps would be turned off.



One way by which a DRED controller is connected to a compatible Samsung air conditioner. There are individual signal wires to switch specific DRM modes connected to a terminal block. Other DRED controllers are connected to the air conditioner by an RJ45 connector (the type used on computer network cables).

DRM2: The appliance is operated at 50% load if it is a variable output device such as an air conditioner. Physically, this typically means the compressor speed is reduced until it is running at 50% of its nominal full power rating.

DRM3: As for DRM2 but the appliance runs at 75% load. This mode was requested by power companies as an incentive to encourage customer uptake of DRED appliances as it was thought no one would want an air conditioner running at only 50% capacity.

There is a futher mode, **DRM4**, which switches an appliance on even if it over-rides timers or other settings. The purpose of this setting is to force appliances to come on when "green" energy is available so they can be run with lower CO_2 emissions. It is not used on air conditioners.

There are also other DRM modes that relate to control of solar panels connected to grid-tied inverters to control their power production These are specified in AS/NZS 4777.2:2015 "*Grid connection of energy systems via inverters – Inverter requirements*".

The AS4755 standard is actually quite vague and only specifies details of connections to an appliance and control of the appliance. Communication from the power utility company to the customer's signal receiver connected to an appliance is open to whatever method the service provider wishes to use.

Communication may be by a ripple signal imposed on the power lines, which seems to have been implemented (at least in some installations) by Energex in Queensland. Ausgrid in trials have used a mobile network 3G device as the signal receiver.

Control may also be via a customer's Internet connected wireless network, broadcast wireless signals, Zigbee, Z-Wave (a home automation protocol) or mesh wireless.

Some air conditioners have some sort of indicator to show they are in DRED mode although not necessarily the particular DRM state they are in. For example, one Panasonic model has the power light flash for three seconds on and 0.5 seconds off, on a certain Mitsubishi model the "run" and "timer" light blink alternately, on Hitachi models all indicator lights on the head units flash.

One of a number of available lists of DRED compatible air conditioners is available via siliconchip.com.au/l/aacf. Some units already have the controller built in, others are ready for it and can have a controller and signal receiver installed.

Presumably, if the DRED service was installed but no longer wanted, because, for example, a sick or frail person needed to be kept in appropriate comfort, then one would have to get permission from the power company to remove it and possibly refund the incentive. A licensed contractor would need to remove the DRM connections to the appliance which should disable it since the control wires are "add on" and DRED control is not currently embedded in the hardware and firmware of the air conditioner.

DRED is a voluntary now but as our electrical grids become more compromised by intermittent renewable energy sources, will it become compulsory in the future?

References

These "shortlinks" will expand to take you to the full website:

siliconchip.com.au/l/aacg
siliconchip.com.au/l/aach
siliconchip.com.au/l/aaci

Installation of DRED devices and signal receivers is only permitted by qualified personnel but if you are interested in some of the details of what is done you may refer to some of these installation guides and videos.

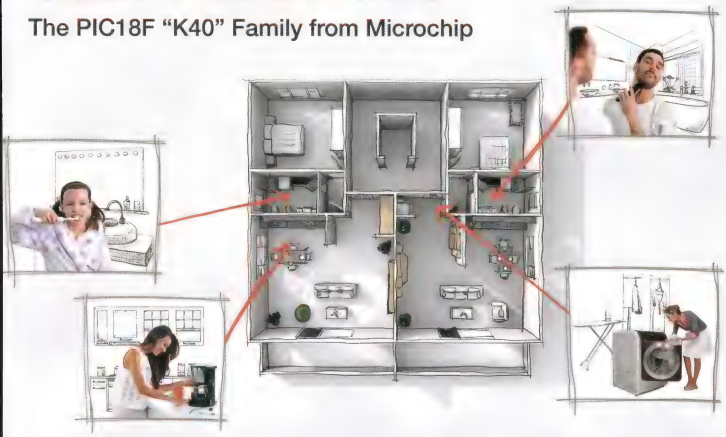
siliconchip.com.au/l/aacj
siliconchip.com.au/l/aack
siliconchip.com.au/l/aacl

SC

Intelligy Demand Response Enabling Device (DRED). It communicates with a smart meter using ZigBee and can be used to control air conditioners, pool pumps and water heaters. Note that this is the signal receiving device. It has to be connected to an appliance via an appropriate AS/NZS 4755.3.5:2016 compliant interface or it can alternately be connected to an auxiliary relay or contactor. A temperature sensor can also be connected to this device.

MCUs That Do More

The PIC18F "K40" Family from Microchip



The term "general purpose MCU" has a new definition. It is no longer necessary to compromise between features and performance. The PIC18F "K40" family of 8-bit microcontrollers gives you the flexibility to handle any embedded application with the performance and efficiency of a purpose-built device. The family's on-chip Core Independent Peripherals can be configured to perform your specific tasks with a fast, deterministic response and class-leading efficiency. Setup and coding is easy using our free graphical configuration tools. Additionally, a wide variety of pin count and memory options ensures a perfect fit in your next design.

Highlights

- High-performance PIC18 MCU core
- 28, 40, and 64 pins with up to 128 KB of Flash
- Code-free, Core Independent Peripherals
- Signal analysis and touch sensing in hardware
- Easy setup with MPLAB® Code Configurator

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AD9833-based Direct Digital Synthesiser

Using Cheap Asian Electronic Modules Part 6

By JIM ROWE

This little signal generator module uses an Analog Devices AD9833 DDS chip and a 25MHz crystal oscillator. It can be programmed to generate sine, triangle or square waves up to 12.5MHz and it's all controlled via an SPI serial interface.

Direct Digital Synthesiser or DDS chips have been around for well over 20 years now but for much of that time they were fairly costly.

Until recently, they didn't include an integral DAC (digital to analog converter), so you had to use their digital output to drive a separate DAC to generate the analog output signal.

In the early 2000s, Analog Devices Incorporated (ADI) announced a new generation of complete DDS devices which did have an integral DAC, as well as offering high performance combined with a price tag significantly lower than what you formerly had to pay for a DDS+DAC combination.

Although it's one of the low-cost, lower-performance devices in their range, the AD9833 provides a good example of just what can be achieved nowadays.

When combined with a 25MHz crystal oscillator, it can be programmed to produce any output frequency from 0.1Hz to 12.5MHz in 0.1Hz increments, with a choice of three waveforms: sine, triangular or square.

All this comes from a chip housed in a tiny MSOP-10 package, running from a supply voltage of 2.3-5.5V, dissipating only 12.65mW and currently with a price tag of $17.46 AUD plus GST in one-off quantities. That's significantly lower than earlier DDS chips.

As we've seen in earlier articles in this series, there has also been a huge surge in the manufacture of many kinds of electronics modules in Asia, especially China, some of them available at surprisingly low prices via internet markets like eBay and AliExpress.

As a result, you can buy the tiny (18 x 13.5mm) AD9833-based DDS module shown in the photos, which includes a 25MHz crystal oscillator, for the princely sum of $7.88 each – including free delivery to Australia! That's really quite a bargain, which is why we're focusing our attention on it this month.

To get an idea of how a DDS works, take a look at the panel titled "DDS in a Nutshell", which can be found on pages 23 & 24 of this article.

Inside the AD9833

The block diagram of Fig.1 shows what's inside that tiny MSOP-10 package. There's quite a lot, although some of the elements are mainly involved in giving the chip its flexibility in terms of output waveform and modulation capabilities. The main sections

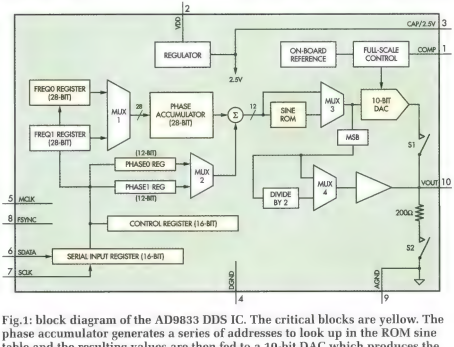


Fig.1: block diagram of the AD9833 DDS IC. The critical blocks are yellow. The phase accumulator generates a series of addresses to look up in the ROM sine table and the resulting values are then fed to a 10-bit DAC which produces the output waveform. Other circuitry allows the output waveform to be changed to a triangle or square wave and also allows for frequency and phase shift keying.

involved in basic DDS operation are those shown with a pale yellow fill.

Down at lower left in Fig.1 you can see the 16-bit shift register where data and instructions are loaded into the chip from almost any micro, via a standard SPI (Serial Peripheral Interface) bus. We'll discuss that in more detail later.

Just above the serial input register is the control register, also 16-bit. This stores the control words, used to set up the configuration of the device, including the output waveform type, which of the two 28-bit frequency registers (FREQ0 or FREQ1) is used to set the DDS output frequency and also whether the phase is shifted by the contents of 12-bit phase registers PHASE0 or PHASE1.

The main reason why the AD9833 has two frequency registers and two phase registers is to give it the capability of generating signals with frequency-shift keying (FSK) or phase-shift keying (PSK) modulation. Multiplexers MUX1 and MUX2 allow these options to be controlled using bits in the control register.

So how are those 28-bit frequency/phase increment registers FREQ0 and FREQ1 loaded with 28-bit data from the 16-bit serial input register? This is done by sending the data in two 14-bit halves, in consecutive 16-bit words from the micro, with the lower half first and then the upper half.

The AD9833 can be configured to accept the data this way simply by manipulating two bits in the control register. The same bits can also be used to configure it for setting either the lower or higher 14-bit "half word" alone, which can be useful for some applications (such as frequency sweeping).

MUX3, MUX4 and switches S1 and S2 are all controlled by further bits in the control register. MUX3 simply allows the sine ROM to be bypassed, with the output from the phase accumulator fed directly to the DAC. This is how the AD9833 produces a triangle wave output, since the amplitude of a triangle wave is a linear function of its phase.

For a square wave output, the DAC is disconnected from the chip's analog output (pin 10) using integrated switch S1, and instead makes use of the MSB (most significant bit) output of MUX3. This automatically gives a square wave output and MUX4 allows you to divide its frequency by two, if needed.

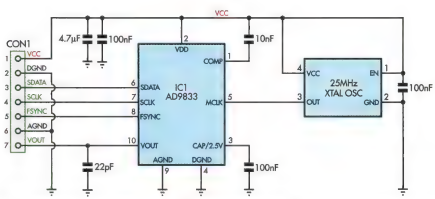


Fig.2: circuit of the AD9833-based DDS module used in this article. The AD9833 IC and 25MHz crystal oscillator plus a few passive components are mounted on a small PCB, with a SIL header to make control and output connections.

The integrated 200Ω resistor connected between the analog output pin and ground via switch S2 is used to convert the DAC's output current into a proportional voltage output. Since S2 is controlled in parallel with S1, this means that when S1 cuts the link between the DAC output and pin 10, S2 also removes the built-in 200Ω output shunt.

This makes the chip's output voltage swing in square wave mode significantly higher than for the sine or triangular (DAC-derived) options.

To be specific, the square wave output is around 5.2V peak to peak, while for sine or triangular waves the output drops to around 650mV peak-to-peak.

The complete module

Now refer to Fig.2, which shows the complete circuit for the 18 x 13.5mm module shown in the photo below.

It simply comprises the AD9833 DDS chip (IC1) and its equally tiny (3 x 2.2mm) 25MHz crystal oscillator. It has six even smaller SMD capacitors, most of them used for filtering either the power supply rails or IC1's V_{OUT} pin.

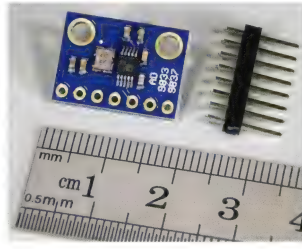
Seven-way SIL connector CON1 is used to make all of the signal and power connections to the module. Pins 1 & 2 are used to provide the module with 5V power, while pins 3-5 are used to convey the SPI commands and data to IC1 from the micro you're using to control it. And pins 6 & 7 are used to carry the analog output signal from IC1 out to wherever it's to be used.

Limitations

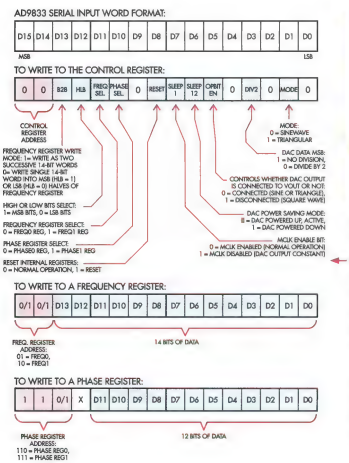
Before we talk about driving the module from a micro like an Arduino or a Micromite, we should discuss its limitations.

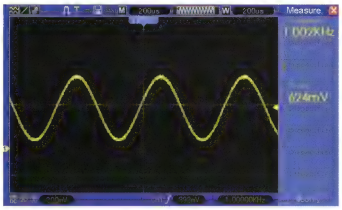
Firstly, the aforementioned difference in output amplitude for square wave versus sine/triangle waves is a factor of about eight times, or 18dB. So if you want to use the module as the heart of a function generator, you will need to attenuate the square wave output by 18dB, to match the sine and triangle output levels.

You will also need to pass the sine and triangular outputs through a low-



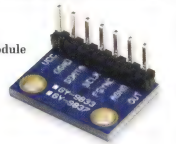
The DDS module is shown at approximately twice actual size to provide greater clarity. From left to right, the pin connections are V_{CC}, DGND, SDATA, SCLK, FSYNC, AGND and V_{OUT}.





Scope 1 (above): a 1000Hz sinewave generated using an Arduino programmed with "AD9833_DDS_module_test.ino".

Fig.3 (left): the format of the 16-bit digital control data sent to the AD9833. The top two bits determine whether the remaining 14 bits are used to update the frequency, phase or control registers. The control register is used to change the output waveform type, switch between two different sets of frequencies and phases or go into a low-power sleep mode.



The underside of the DDS module with the 7-pin male header attached. Again, it's shown twice actual size, due to its small size (18 x 13.5mm).

pass filter with a corner frequency of around 12-15MHz, to remove most of the DAC switching transients. After this processing, the outputs can all pass through a common buffer amplifier and output attenuator system.

You don't need to worry about any of these niceties if you simply want to use the module as a programmable clock signal source. You can just program it to generate a square wave output and use it as is.

Another limitation, as noted in the "DDS in a Nutshell" box, is that the maximum output frequency is half the sampling clock frequency; in this case, 12.5MHz. But because of the way a DDS works, it can only produce a clean square wave at this maximum frequency.

If you want to get a reasonably smooth sine or triangular wave output, this will only be possible at frequencies below about 20% of the clock frequency, or in this case, a maximum of about 5MHz.

Programming it

When your program starts up, it will need to carry out a number of set-up tasks. These include:

1. Declare the micro's pins that are going to be used by the SPI interface and set them to their idle state (typically high).
2. Start the SPI interface, configured

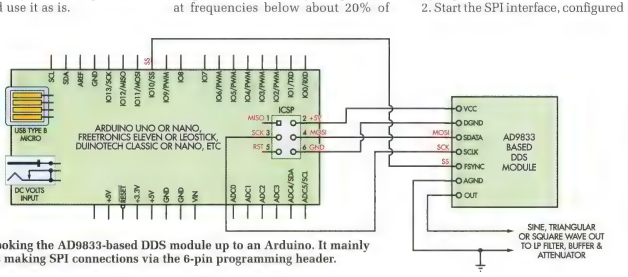
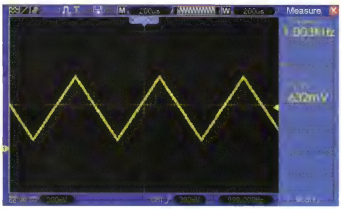
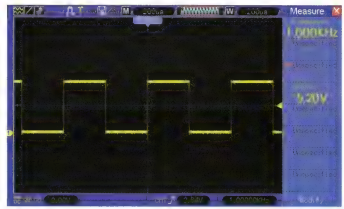


Fig.4: hooking the AD9833-based DDS module up to an Arduino. It mainly involves making SPI connections via the 6-pin programming header.





Scope 2 & 3: a 1000Hz triangular (left) and square (right) wave produced by running the "AD9833_DDS_module_test.ino" file on an Arduino or compatible device. Note the higher amplitude of the square wave output.

for a clock rate of say 5MHz, the data to be sent MSB (most significant bit) first and using clock/data timing mode 2 (10 binary). If possible, it should also be set for the data to be exchanged in 16-bit words rather than bytes.

3. Send initialisation commands to the AD9833 to set up its control register, the FREQ0 register and the PHASE0 register. These involve sending the following five 16-bit words (shown here in hexadecimal):

- 0x2100 (resets all registers, sets control register for loading frequency registers via two 14-bit words)
- 0x69F1 (lower word to set FREQ0 for 1000Hz)
- 0x4000 (upper word to set FREQ0 for 1000Hz)
- 0xC000 (writes 000 into PHASE0 register)
- 0x2000 (write to control register to begin normal operation)

With that, the DDS should produce a 1000Hz sinewave. To change to one of the other waveforms, you need to send the correct code to the control register. To change the output frequency, you need to send the appropriate pair of 14-bit words to one of the frequency registers. Note that these are sent lower word first, then upper word.

To make programming the AD9833 a little easier, the basic coding for the control, frequency and phase registers is summarised in Fig.3. I also have written a couple of simple example programs to illustrate programming the AD9833 module; more about these shortly. First you'll need to know how the module can be connected to one of the popular micros.

Driving it from an Arduino

Fig.4 shows how to connect the module up to almost any Arduino or Arduino clone.

This takes advantage of the fact that most of the connections needed for interfacing to an SPI peripheral are made available on the 6-pin ICSP header fitted to most Arduino variants.

The connections to the ICSP header are quite consistent over just about all Arduino variants, including the Uno, Leonardo and Nano, the Freetronics Eleven and LeoStick, and the Duinotech Classic or Nano.

In fact, the only connection that's not available via the ICSP header is the one for SS/CS/FSYNC, which needs to be connected to the IO10/SS pin of an Arduino Uno, Freetronics Eleven or Duinotech Classic, as shown in Fig.4.

With other variants, you should be able to find the corresponding pin without too much trouble. Even if you can't, the pin reference can be changed in your software sketch to match the pin you do elect to use.

Arduino sample program

One of my sample programs written for an Arduino is called "AD9833_DDS_module_test.ino".

It simply initialises the AD9833, starts generating a 1000Hz sinewave (Scope 1) and then changes the waveform after five seconds, giving you a triangular wave (Scope 2), then a square wave (Scope 3) and finally a half-frequency square wave, before returning to a sinewave and repeating the sequence. If you look at the code, you can see how easy it is to control the AD9833 DDS module from an Arduino.

Driving it from a Micromite

Fig.5, on the next page, shows how to drive the module from a Micromite. By connecting the MOSI, SCK and SS/FSYNC lines to Micromite pins 3, 25 and 22 as shown, MMBasic's built in SPI protocol commands will have no trouble in communicating with the module.

One thing to note is that if you want to drive the AD9833 module from a Micromite in a BackPack that is already connected to an LCD touchscreen, there's a small complication arising from the fact that the LCD touchscreen also communicates with the Micromite via its SPI port.

To prevent a conflict, your program needs to open the SPI port immediately before it sends commands or data to the module, and then close the port again immediately afterwards.

Micromite sample program

My other program is written for the Micromite, specifically, the Micromite LCD BackPack. It's called "Simple AD9833 FnGen.bas".

This one is a little more complicated and lets you control the AD9833's output frequency as well as the waveform, simply by using buttons and a virtual keypad on the Micromite's touch screen. It's quite easy to drive, and again should show you how the AD9833 can be controlled via a Micromite.

Both this program and the Arduino program are available for download from the SILICON CHIP website (www.siliconchip.com.au).

Alternative module

On page 68 of this issue, we have published a Micromite-based DDS Function Generator project by Geoff Graham which also uses the AD9833. Geoff has used a slightly different module which includes the ability to vary

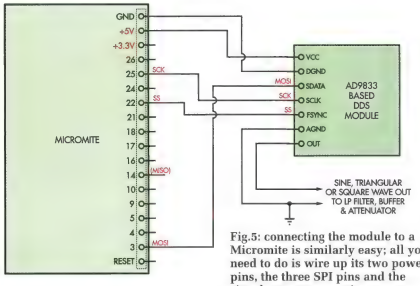


Fig.5: connecting the module to a Micromite is similarly easy; all you need to do is wire up its two power pins, the three SPI pins and the signal output connections.

the output level and also has a low-impedance buffered output.

The module Geoff has used is shown below, to the left of its circuit diagram, Fig.6. It differs from the simpler module shown in Fig.2 in that it has the output signal from the AD9833 fed to a separate SIL connector.

From there the signal is routed to an MCP41010 10kΩ digital potentiometer IC via a 0Ω resistor, which acts as a digitally controlled attenuator. The output of this attenuator is fed to an AD8051 rail-to-rail op amp and together these constitute a PGA, or Programmable gain amplifier (not pin grid array).

The digital pot also communicates via SPI and in fact its clock and data pins are wired up in parallel with the AD9833's so it is on the same SPI bus.

The only difference in communication is rather than pulling the FSY pin low, as you do to communicate with the AD9833, you pull the CS pin low to communicate with the MCP41010.

Like the AD9833, the MCP41010 is controlled by writing 16-bit data words to it. For the MCP41010, the bottom eight bits of the data are the new potentiometer position while the upper eight bits contain two command bits, two channel selection bits and four "don't care" bits, which it ignores.

The command bits allow you to select whether you are setting the pot wiper position or commanding the IC go to into a power-down mode.

We suggest you check its datasheet for details, however, you really only need to send one of two different commands to this device when using this module:

0x11xy – set wiper position to 8-bit value xy

0x2100 – shut down potentiometer, saving power and disabling the output signal

For example, the command 0x11FF will set the output level to maximum, command 0x1180 will set the output level to 50% and 0x1101 will set it to the minimum non-zero level.

The attenuated output signal is available at pin 6 and this goes to the non-inverting input of an AD8051 high-frequency op amp which is configured with a gain of six times, providing an output swing of around 3V peak-to-peak for sine and triangle waves. This signal is fed to both a 2-pin header connector and SMA socket via another 0Ω resistor.

Other variations in this module are that it has 100Ω protection resistors for

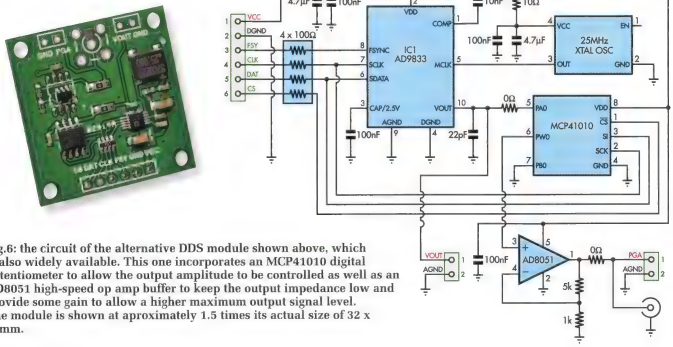


Fig.6: the circuit of the alternative DDS module shown above, which is also widely available. This one incorporates an MCP41010 digital potentiometer to allow the output amplitude to be controlled as well as an AD8051 high-speed op amp buffer to keep the output impedance low and provide some gain to allow a higher maximum output signal level. The module is shown at aproximately 1.5 times its actual size of 32 x 32mm.

the four control pin inputs, the supply for the 25MHz crystal oscillator has a 10Ω isolating resistor that also forms a low-pass filter in combination with the added 4.7µF ceramic capacitor and there is a 2-pin header which makes the output of the AD9833 available, before it enters the attenuator.

There are more details on how to use this module in this month's article on the Micromite-based DDS Function Generator, but besides needing to program the digital pot with the attenuation value, its control is pretty much identical to the description above.

Final comments

In the June 2016 issue of SILICON CHIP, on pages 86-87, we published a "Touch-screen Function Generator" design by NSW reader Dan Amos. Mr Amos' design used an AD9833 module driven by a Micromite with an LCD BackPack but he also added a digital potentiometer, an output buffer amplifier and even an incremental encoder for adjusting either the output frequency or its amplitude.

He also provided the MMBasic source code for his program, and a user manual as a PDF file – both of which can be downloaded from the SILICON CHIP website. So that project and its software is also an excellent example to get you started on using the AD9833 DDS module.

One last comment before closing. As well as being able to generate fixed frequency, FSK and PSK modulated signals, the AD9833 can also be programmed to generate swept-frequency signals.

In fact, the Micromite DDS Function Generator in this issue does just that, so refer to that article on page 68 for more details on frequency sweeping.

DDS in a Nutshell

This simplified explanation should give you some insight into how a DDS works. A DDS is based around one or more look-up tables stored in read-only memory (ROM). These contain a set of high-resolution digital samples of a single wave cycle.

Let's consider the case where the table contains a sinewave.

The values from the ROM table are fed to a DAC (digital-to-analog converter), so that for each entry in the table, the DAC will produce an analog DC voltage corresponding to the value of the sample stored in that address.

As a result, if a counter is used to cycle through the table entries continuously, the DAC output is a continuous sinewave.

Let's say that the table contains 1000 entries which represent a single sinewave cycle and the counter which indexes the table is incremented at a rate of 1MHz.

This means that the output will be a sinewave at 1MHz ÷ 1000 = 1kHz. By changing the rate at which the counter increases, we can change the output frequency.

Since the DDS chip operates from a fixed external clock, in order to vary the rate at which the DDS runs through its ROM table, a fancier counter configuration known as a "phase accumulator" is used. This is shown in Fig.7 and it consists of a binary adder feeding an accumulator register.

The important point to note is that the phase accumulator register has 28 bits of precision while the sample table, with 4096 entries, only requires a 12-bit number to index its entries.

Hence there are an additional 16 bits of fractional phase data in the register and these effectively indicate output phase values in-between those represented by the values in the table.

The binary adder has two 28-bit inputs, one of which is the current phase value from the accumulator register. The other input comes from the frequency register at far left, also 28 bits wide.

This is the register which we use to set the DDS output frequency. At each clock cycle, the value in the frequency register is added to the value in the accumulator register and this result is stored back in the accumulator register. As a result, as long as the frequency register value doesn't change, the accumulator register increases by the same amount on each clock cycle.

With a 28-bit phase accumulator register, a value of zero indicates a phase in radians of zero while its maximum value of 2^{28} - 1 (268,435,455) represents a phase of just under 2π.

When the value of the accumulator register exceeds 2^{28} - 1, it rolls back around to zero, hence maintaining $0 \leq \text{phase} < 2\pi$. Each time it "rolls over", that represents one complete cycle from the output.

With a frequency register value of 1, it will take 2^{28} clock cycles for this to happen. With a master clock of 25MHz, that means the output frequency will be 25MHz ÷ 2^{28} = 0.09313Hz or just under 0.1Hz.

With a frequency register value of 2, it will take $2^{28} \div 2$ clock cycles to roll over, giving an output frequency of 25MHz ÷ 2^{27} = 0.186Hz and so on.

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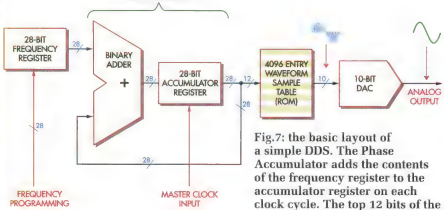

Fig.7: the basic layout of a simple DDS. The Phase Accumulator adds the contents of the frequency register to the accumulator register on each clock cycle. The top 12 bits of the accumulator register is then used to look up an entry in the waveform table ROM, producing a 10-bit digital amplitude value which is subsequently fed to the digital-to-analog converter (DAC) to generate the analog output signal.

So the output frequency resolution with this configuration is just under 0.1Hz.

But how are such low frequencies possible with only a 4096-entry table? Well, only the top 12 bits of the 28-bit accumulator register are used to index the ROM table.

This means with the minimum frequency value of one, it will only roll over to the next entry in the table once every $2^{(28-12)} = 65,536$ clock cycles. Hence, each value from the table is sent to the DAC 65,536 times before progressing to the next one, giving a very low frequency.

At higher frequencies, in this case above 25MHz ÷ 4096 (6.103kHz), values in the table will be skipped when necessary in order to increase the output frequency. In other words, the counter which indexes the table may increase at a rate of 1, 2, 3, 4 times per clock, or somewhere in-between, by skipping the occasional table entry.

For example, to produce an output of 12.207kHz, every second entry from the ROM table is sent to the DAC (12.207kHz = 25MHz ÷ [4096 ÷ 2]).

Based on the above, we can calculate the output frequency as:

$$Fo = Dph \times Mclk \div Rac$$

For the DDS shown in the diagram, with a 28-bit phase accumulator having a resolution (Rac) of 2^{28} (= 268,435,456) and with a master clock frequency (Mclk) of 25MHz, this simplifies down to:

$$Fo = Dph \times 0.09313$$

By the way, while we're showing the table as containing 4096 entries, note that due to symmetry, it's only actually necessary to store the values representing one quarter of a sine-wave.

The second quadrant of a sine-wave is a mirror-image of the first, so this can be achieved by running through a quarter sine table backwards, while the third and fourth quadrant are simply an inverted version of the first and second, and these can be obtained by negating the values from the first two quadrants.

You'll also notice that the samples stored in the ROM are shown as having a resolution of 10 bits, to suit the 10-bit DAC, which can produce an analog output with 1024 different voltage levels.

One more thing to bear in mind. Because a DDS achieves higher output frequencies by skipping samples in the waveform ROM, at higher output frequencies, the sampling resolution effectively drops.

This continues until you reach the "Nyquist frequency" of half the master clock frequency (ie, 12.5MHz) above which the output from the DAC actually starts to drop in frequency.

So the theoretical maximum frequency for a DDS is half that of the master clock.

But in practice, because of the above, if you want a reasonably smooth sinewave output that doesn't need too much low-pass filtering, it's a good idea to limit the maximum output frequency to about 20% of the master clock frequency; say 5MHz for a 25MHz master clock. SC

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For all the musos (and budding musos!) out there . . .

SPRING REVERB

Way back in the January 2000 issue, we published a Spring Reverberation project for musicians which was described as a "blast from the past". Well, you had better prepare for a second explosion because this new unit uses a much cheaper, readily available spring "tank" and has a more flexible power supply, so you can easily build it into your favourite amp, even if it's portable.

by Nicholas Vinen

Despite the availability of digital reverb and effects units these days many musicians, especially guitarists, still like the "old school sound" of spring reverberation.

Put simply, a reverberation effects unit takes the dull sound of an instrument (including the human voice) being played in a "dead" space and adds lots of little echoes.

These simulate what it sounds like to perform in an acoustically complex space such as an auditorium, which has lots of difference hard surfaces for sound waves to reflect off, making for a much more "live" sound.

Even if you're playing in a decent hall, adding extra reverb can make the hall sound bigger and grander. It's also a great way to help a beginner musician sound more professional.

To simulate all these acoustic reflections, rather than using digital processing, a spring reverb uses a spring "tank" comprising two or more actual springs.

Sound waves are generated at one end of the springs using a voice coil, much like a tiny speaker, and just as sound waves travel through air, they will also happily travel down the metal springs. They are picked up at the other end by what is essentially a microphone.

Only, because of the (for lack of a better word) springiness of the springs, and the way they are suspended at either end, the audio signal doesn't just travel down the springs, it bounces around, generating echoes and since no physical process is 100% efficient, these decay, just like sound waves do when they bounce off walls, floors, ceilings, chairs and other objects.

It's a personal preference but many prefer this effect to a digitally generated one.

The end result is something you really have to hear to appreciate but it's surprising just how good a job the spring tank does of mimicking sounds bouncing around a hall.

Of course, the exact sound depends upon the exact tank used – some have two springs, some have three, some are longer or shorter and so on – but regardless of how natural it is, chances are you will find some configuration where it will add an extra dimension to your performance.

And being electronic, you can vary the reverb effect's intensity (or "depth") and turn it on or off as necessary. But unlike a digital effects unit, you can't easily change other parameters such as the echo delay or frequency response.

Our previous Spring Reverb design from January 2000 worked well but neither the PCB nor the spring tank (which was sourced by Jaycar) is available

Features and specifications

Reverb tank type: two spring
Anti-microphonic features: spring suspension, plastic mounting bushings
Spring tank dimensions: 235 x 87 x 34mm
Reverb delay times: 23ms, 29ms (see Figs.4 & 5)
Reverb decay time: around two seconds (see Fig.6)
Input sensitivity: ~25mV RMS
Frequency response (undelayed signal): 20Hz-19kHz (-3dB) (see Fig.2)
Frequency response (reverb signal): 200Hz-3.4kHz (-3dB) (see Fig.2)
Signal-to-noise ratio (undelayed signal): 62dB
Signal-to-noise ratio (typical reverb setting): 52dB
THD+N (undelayed signal): typically around 0.05% (100mV signal)
Controls: level, reverb depth, reverb on/off
Power supply: 9-15VAC, 18-30VAC centre tapped or 12-15V DC
Quiescent current: typically 30-40mA

You might think of it as "olde world" but there's a surprising number of musos who say that a spring reverb ALWAYS sounds better than a digital unit!

now. So here is a revised unit which has some worthwhile extra features.

Sourcing the spring tank

Fortunately, there are multiple suppliers of spring reverb tanks. You guessed it; most of them seem to be in China.

The one we're using is from a musical instrument component supplier called Gracebuy based in Guangdong and at the time of writing this, you could purchase the tank for US$20.37 including free postage via the following "shortlink": siliconchip.com.au/l/aac8.

(The shortlink, either typed in or clicked on in this feature in siliconchip.com.au, will redirect to the supplier's page without you having to type in four lines of URL!)

The same supplier sells this same unit on ebay, including free postage, for $26.00 AUD via the following shortlink: siliconchip.com.au/l/aac9

If you search ebay, you can also find other units including some with three springs and/or longer springs. We haven't tried any of these but we would expect them to work with our circuit with little or no modification. So if you're feeling adventurous, here are some examples:

siliconchip.com.au/l/aaca
siliconchip.com.au/l/aacb
siliconchip.com.au/l/aacc

You can get an idea of the properties of the tank we're using by looking at the scope screen grabs in Figs.4-7.

Three spring units will have triplets of echoes, rather than pairs, and longer units will have a larger gap between the stimulus and echo. Other tanks may also have a shorter or longer persistence time than the one we've used, depending on the properties of the springs themselves.

Note that most of the alternative tanks are larger than the one we've used (which is fairly compact; see the specifications panel) so make sure you have room for it in your amplifier's chassis (or wherever you plan to fit it) before ordering one.

Improvements to the design

Besides adapting the original January 2000 circuit to give the best performance with the new spring tank, we

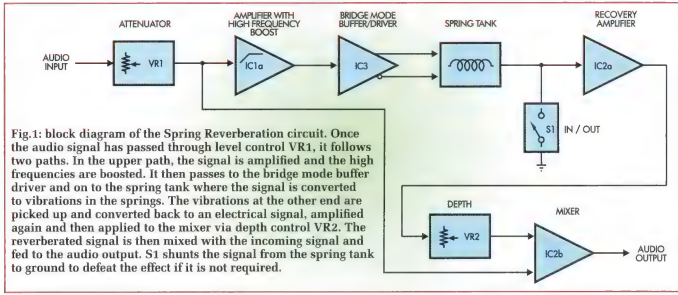


Fig.1: block diagram of the Spring Reverberation circuit. Once the audio signal has passed through level control VR1, it follows two paths. In the upper path, the signal is amplified and the high frequencies are boosted. It then passes to the bridge mode buffer driver and on to the spring tank where the signal is converted to vibrations in the springs. The vibrations at the other end are picked up and converted back to an electrical signal, amplified again and then applied to the mixer via depth control VR2. The reverberated signal is then mixed with the incoming signal and fed to the audio output. S1 shunts the signal from the spring tank to ground to defeat the effect if it is not required.

also simplified it somewhat, to make it easier to build and reduce the cost. Plus, we made wiring it up and mounting it in an amplifier significantly easier, by the use of more on-board components and connectors.

However, the main improvement is the ability to run off a DC supply. This was added so that buskers can add a spring reverb function to portable amplifiers, which may be powered by a 12V lead-acid battery or similar. In fact, the PCB is quite flexible and can be powered from 9-15VAC, 18-30VAC (centre-tapped) or 12-15V DC.

It's also possible to modify it to run off 15-30V DC, in which case you may need to increase the voltage ratings of the 1000µF and 220µF capacitors.

One small extra feature we've added, besides the new power supply options and related changes, is an indicator LED to show whether the reverb effect is active. It's built into the reverb on/off pushbutton switch, S1.

Basic concept

A block diagram of the Spring Reverb unit is shown in Fig.1. The level of the incoming signal (from a guitar, keyboard, microphone, preamp, etc) is adjusted using potentiometer VR1 and is then fed both to a preamplifier for the spring tank and to a mixer, which we'll get to later. The preamplifier boosts high frequencies since the transducer which drives the springs is highly inductive and so needs more signal at higher frequencies to produce sufficient motion in the springs.

Between the preamp and the tank is the buffer stage which has little gain but serves mainly to provide sufficient current to drive the transducer, which it does in bridge mode, for reasons explained below.

The output of the spring tank, which is delayed compared to the input and contains all the added reverberations, is fed to switch S1 which can shunt the signal to ground if reverb is not currently required. Assuming the signal is not shunted, it is fed to a recovery amplifier which boosts its level back up to a similar level to the input signal and then on to VR2, which is used to attenuate the reverberations in order to control the intensity or "depth" of the effect.

The attenuated reverberations are then fed to the mixer where they are mixed with the clean input signal to produce the final audio output, which can then be fed to an amplifier or mixer.

Circuit description

The complete circuit for the Spring Reverb module is shown in Fig.3. Note that two different ground symbols are used in the circuit. For the moment, you can consider them equivalent; we will explain the significance later, when we go over the power supply details.

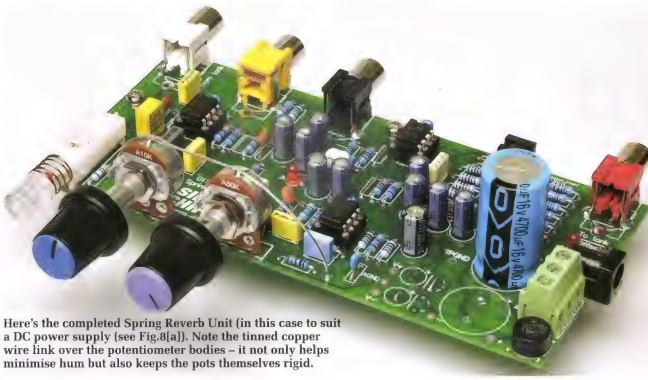
The signal from the guitar/preamp/etc is applied via RCA connector CON1 and then passes through a pair of electrolytic capacitors connected back-to-back (ie, in inverse series), which effectively form a bipolar electrolytic capacitor, to prevent any DC component of the signal from reaching the rest of the circuitry.

The signal then goes through low-pass/RF filter comprising a 100Ω resistor, 4.7nF MKT capacitor and a ferrite bead. The -3dB point of the low-pass filter is around 340kHz while the ferrite bead helps attenuate much higher frequency signals (eg, AM and CB radio) which may be picked up by the signal lead. Both filters help prevent radio signal break-through. The audio signal then passes to 50kΩ logarithmic taper potentiometer VR1 which forms an input level control.

The level-adjusted signal from the wiper of VR1 goes to two different parts of the circuit, as shown in the block diagram (Fig.1); to the mixer, via a 47nF AC-coupling capacitor and to the tank drive circuit, via a 100nF AC-coupling capacitor. We'll look at the latter path first before coming back to the mixer later. The 100kΩ DC-bias resistor at input pin 3 of IC1a forms a high-pass filter in combination with the 100nF coupling capacitor, which has a -3dB point of 16Hz.

Note that in the original design, this part of the circuit used a 10nF capacitor which gave a -3dB point of 160Hz. The reason for having such a high roll-off was two-fold: firstly, the tank used previously had a very low input DC resistance and presenting it with a high-amplitude, low-frequency signal risked overloading the driving circuitry. And secondly, this helped attenuate 50/100Hz mains hum and buzz that may be from the guitar, cabling and so on.

Additionally, while it is possible to get good low frequency performance, it's generally undesirable because it



Here's the completed Spring Reverb Unit (in this case to suit a DC power supply (see Fig.8[a]). Note the tinned copper wire link over the potentiometer bodies – it not only helps minimise hum but also keeps the pots themselves rigid.

tends to muddy the sound.

We've shifted this -3dB point down because the transducer in the tank we're using this time has a much higher DC resistance and we've beefed up the driving circuitry, so overload is less of a problem, and this makes the reverb sound less "tinny".

However, you still have the option of reducing this capacitor value, possibly back to the original 10nF, if you find the unit has excessive hum pick-up. It really depends on your particular situation whether this is likely. Note though that this solution to hum is a case of "throwing the baby out with the bathwater"; at the same time as reducing the hum pick-up, you're also filtering out any genuine signals at similar frequencies.

Getting back to the signal path, IC1a operates as a non-inverting amplifier with a maximum gain of 101 times, as set by the ratio of the 100kΩ and 1kΩ resistors.

The 10nF capacitor in series with the 1kΩ resistor causes the resistance of the lower leg of the voltage divider to increase at lower frequencies, thus reducing the gain at lower frequencies. For example, a 10nF capacitor has an impedance of 16kΩ at 1kHz, thus the gain at 1kHz is reduced to 100kΩ ÷ (1kΩ + 16kΩ) + 1 = 6.9 times. The slope of the resulting filter is 6dB/octave and the -3dB point is 16kHz, which not coincidentally, happens to be the frequency at which a 10nF capacitor has an impedance of 1kΩ. In other words, the gain is reduced to about half its maximum (ie, 51 times) at 16kHz. You can see the effect of this filter stage in the frequency response diagram of Fig.2.

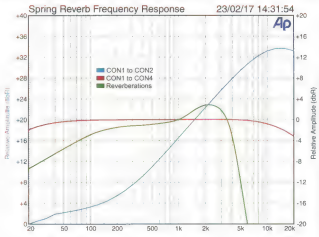


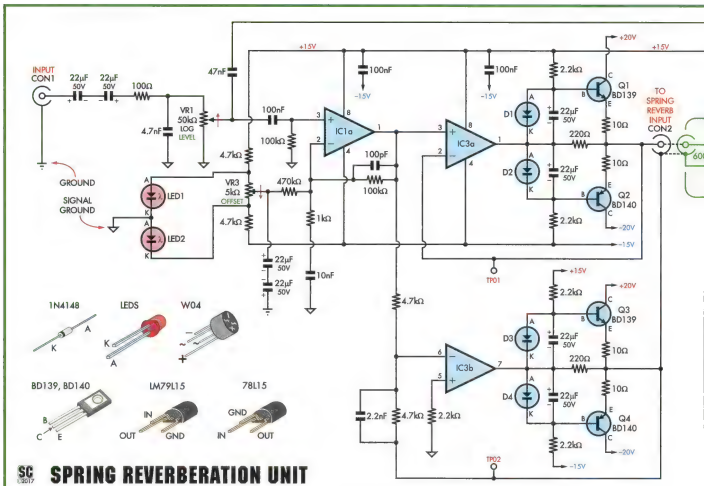
Fig.2: three frequency response plots for the Reverb unit. The frequency response from input connector CON1 to spring tank driver connector CON2 is shown in blue and uses the left-hand Y-axis. The unit's overall frequency response, ignoring reverberations, is shown in red. The approximate frequency response for the reverberations is shown in green. This is difficult to measure since pulse testing must be used, otherwise standing waves cause constructive and destructive interference. Our curve is based on pulse testing at discrete frequencies and can be considered an approximation of the actual response.

This 10nF capacitor also prevents the input offset voltage of IC1 from being amplified and creating a large DC offset at the output, while the 100pF capacitor across the 100kΩ resistor reduces the gain of this op amp stage at very high frequencies, preventing instability and also reducing the effect of RF/hum pick-up in the PCB tracks. The -3dB high-frequency roll-off point due to this capacitor is 16kHz.

Tank drive circuitry

Because the spring tank we're using has a fairly high input impedance of 600Ω at 1kHz, and because the springs themselves are quite lossy, the signal fed to the tank needs to have as large an amplitude as we can provide, given the supply rails available.

Note that the supplier lists the tank input DC resistance as 28Ω and its inductance as



SC 2017

SPRING REVERBERATION UNIT

Fig.3: complete circuit for the Spring Reverberation Unit, including the spring tank connected between CON2 and CON3 (shown in green). Only the output socket of the spring tank is connected to its case – this is to avoid earth (hum) loops. Note also that two different ground symbols are used; depending on the power supply arrangement, they may be connected together, or the signal ground may sit at half supply when powered from DC. Two different power supply arrangements are shown in the boxes at right and the PCB can be configured for one or the other. With an AC input, the circuit is powered from regulated, split rails of nominally ±15V while with a DC supply, the circuit runs off the possibly unregulated input supply.

Table 1 – expected voltages relative to TPGND

Supply	"+"	"–"	V+	V-	AGND
15VAC	+20V	-20V	+15V	-15V	0V
12VAC	+17V	-17V	+12V	-12V	0V
9VAC	+12V	-12V	+9V	-9V	0V
12V DC	+12V	0V	+12V	0V	+6V *(half V+)*

23mH but the actual measured figures are 75Ω and 83mH, giving an input impedance of just under 600Ω at 1kHz.

With ±15V supply rails, the LM833 and TL072 low-noise op amps we're using have a maximum output swing of around ±13.5V or 9.5V RMS. But since we've also designed this unit to be able to run off a 12V lead-acid battery (or equivalent) for busking purposes, and with a supply of only 12V, the output swing is much more limited at 9V peak-to-peak or just 3.2V RMS.

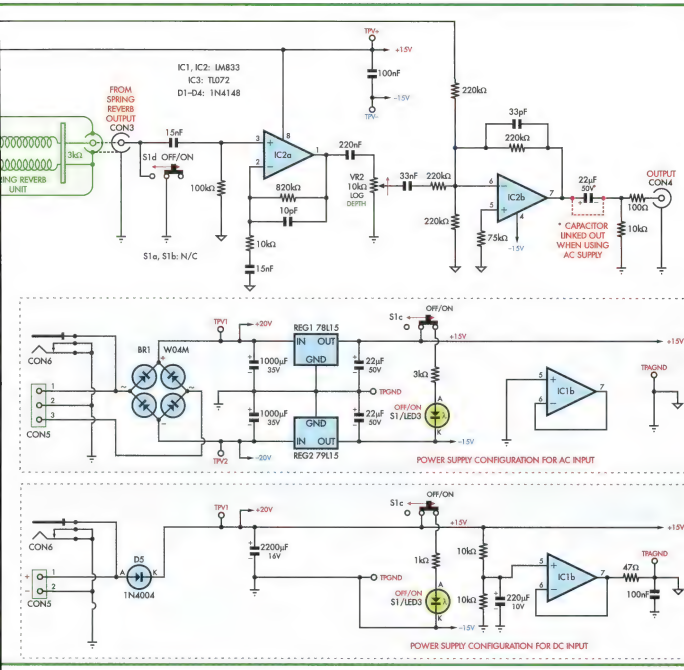
To improve this situation, we've redesigned the circuitry to drive the tank in bridge mode. This is possible since the driving transducer's negative input is not connected to its earthed chassis. That doubles the possible signal when running from a 12V DC supply, to nearly 6.5V RMS.

It works as follows. The output signal from gain/filter stage IC1a passes to both halves of dual op amp IC3. In the case of IC3a, it is fed directly to the non-inverting input at pin 3, while for IC3b, it goes to the inverting input at pin 6 via a 4.7kΩ resistor.

IC3a operates as a unity-gain power buffer. The output signal from pin 1 of IC3a goes to the tip connector of CON2 and hence the transducer in the spring tank via a 220Ω series resistor but pin 1 also drives the bases of complementary emitter-follower pair Q1 and Q2 via two 22µF capacitors.

A DC bias voltage of around 0.7V is maintained across these capacitors due to the current flowing from the regulated V+ rail (typically +15V), through a 2.2kΩ resistor, small signal diodes D1 and D2, another 2.2kΩ resistor and to the V- rail (typically -15V). You can calculate the current through this chain at around (30V - 0.7V x 2) ÷ (2.2kΩ x 2) = 6.5mA and this current sets the forward voltage across D1 and D2 and thus the average voltage across those two capacitors.

The voltage across these capacitors defines the quiescent base-emitter



voltage of both Q1 and Q2 and thus their quiescent current, which is around 10mA. This is necessary to prevent significant crossover distortion when drive is being handed over between Q1 and Q2, as the output signal passes through 0V.

The two 10Ω emitter resistors help to stabilise this quiescent current by way of local negative feedback, since as the current through Q1 or Q2 increases, so does the voltage across these resistors, which reduces the effective base-emitter voltage.

The signal fed to the tank is also fed back to inverting input pin 2 of IC3a, setting the gain of this stage at unity. This closes the op amp feedback loop around Q1, Q2 and associated components.

The outer "ring" terminal of CON2, which connects to the opposite end of the tank drive transducer, is driven by an almost identical circuit based on IC3b and transistors Q3 and Q4. However, so that the transducer is driven in bridge mode, the gain of this stage is -1, ie, it is an inverting unity-gain amplifier.

This is achieved by connecting its pin 5 non-inverting input to signal ground a 2.2kΩ resistor and then using a 4.7kΩ feedback resistor and a 4.7kΩ resistor between the inverting input (pin 6) and the output of the previous stage, pin 1 of IC1a. The 2.2nF feedback capacitor rolls off the gain of this stage at high frequencies, giving a -3dB point of 16kHz and ensuring stability. The tank doesn't do much to preserve frequencies above 5kHz anyway.

By the way, we're using a TL072 op amp for IC3 instead of an LM833, as used for IC1 and IC2, because its lower bandwidth (and other aspects of the internals of this IC) makes it better suited for driving a complementary emitter-follower buffer. If you use an LM833 instead, the circuit will work but there is likely to be a spurious low-

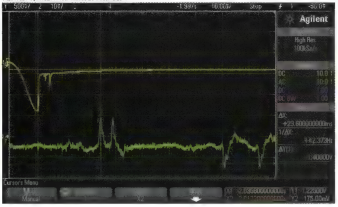


Fig.4: the yellow trace shows the signal fed to the spring tank input while the green trace at bottom shows the signal at the spring tank output. 23.6ms after a pulse is applied to the input, it appears at the output and then a second echo appears around 29ms after the initial pulse. You can see the next set of echoes due to the signal travelling up and down the springs again some 45ms later and note that each set of echoes has opposite polarity compared to the last.

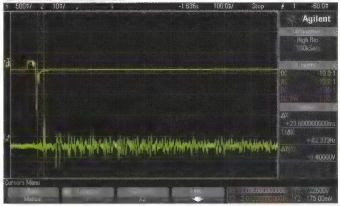


Fig.5: the same signal as shown in Fig.4 but this time at a slower timebase, so you can see how the reverberating echoes continue on for some time after the initial pulse, slowly decaying in amplitude.

level ~1MHz signal injected which might upset the power amplifier.

This signal is due to the op amp having trouble coping with the extra phase shift introduced due to the transistors in its feedback path and it's hard to tame without adding some gain to the buffer stage, which we don't really need. Using a TL072 instead solves the problem and since all the gain is handled by the other two LM833 op amps (which have a lower noise figure), it doesn't degrade the performance at all.

Output offset adjustment

Since the transducer in the tank has a relatively low DC resistance, we'd like to avoid a high DC offset voltage across CON2 as this will waste power and heat up both the transducer and Q1-Q4 unnecessarily. This was absolutely critical with the older Spring Reverb unit as the transducer used then had a very low DC resistance (under 1Ω). While not as critical anymore, we've left the DC offset adjustment circuitry in place as it's relatively simple and cheap.

But because the new Reverb unit can run off an unregulated DC supply, we've changed it so that no longer relies on the regulated supply rails to provide a consistent offset adjustment.

Red LED1 and LED2 are connected across the supply rails with 4.7kΩ current-limiting resistors. The junction of LED1's cathode and LED2's anode is connected to signal ground. As a result, LED1's anode is consistently around 1.8V above signal ground while LED2's cathode is consistently about 1.8V below signal ground.

VR3 is connected between these two points and so the voltage at its wiper can be adjusted between these two voltages. Two back-to-back 22µF capacitors stabilise this voltage so it does not jump around when power is first applied and the supply rails are rising. A 470kΩ resistor between VR3's wiper and pin 2 of IC1a allows VR3 to slightly increase or decrease the voltage at that pin, to cancel out any offset voltages in op amps IC1a, IC3a and IC3b.

Note that because IC3a has a gain of +1 and IC3b has a gain of -1, when you turn VR3 clockwise, the output voltage of IC3a will rise slightly while the output voltage of IC3b will drop slightly. Thus, there will be a position of VR3 such that the output voltages of these two op amps are identical when there is no input signal. This is the condition we're aiming for as it minimises DC current flow through the transducer connected to CON2.

Signal recovery

The signal passes through the springs in the tank as longitudinal vibrations and these are picked up at the opposite end by another transducer which is connected to the board via CON3. The signal from this second transducer is roughly -60dB down compared to the signal going in, so it is fed to another high-gain stage based around op amp IC2a, through another coupling/high-pass filter comprising a 100nF capacitor and 100kΩ resistor, with a -3dB point of around 16Hz.

Switch pole S1f is shown in the on position; in the off position, it shorts the signal from the tank to ground, so there is effectively no reverb.

IC2a is configured as a non-inverting amplifier with a maximum gain of 83 times (820kΩ ÷ 10kΩ + 1). However, like IC1a, its gain is reduced at lower frequencies due to the 15nF capacitor in the lower leg of the divider, with a -3dB point of around 1kHz. As before, a capacitor across the feedback resistor ensures stability and reduces gain at very high frequencies; in this case, it is 10pF.

The recovered signal from the tank is then AC-coupled to 10kΩ log potentiometer VR2 via a 220nF capacitor. VR2 controls the level of the reverb signal which is fed to the mixer and thus the "depth" of the reverb effect. The resulting signal at its wiper is then coupled to inverting pin 6 of mixer op amp IC2b via a 33nF AC-coupling capacitor and 220kΩ series resistor.

The reason for using two coupling capacitors with VR2 is to prevent any DC current flow through it, which could cause crackling during rotation as the pot ages (note that we have done the same with VR1).

The mixer

Now you may remember that the signal from VR1 was fed both to the

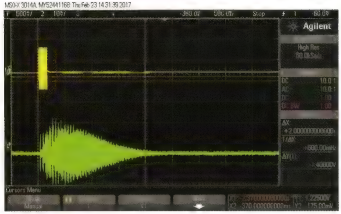


Fig.6: this time we have a longer stimulus pulse, again shown in yellow, and the response shown in green on a much longer timebase. The reverberations continue for several seconds after the initial pulse but they have mostly died out after around two seconds (indicated with the vertical cursor).

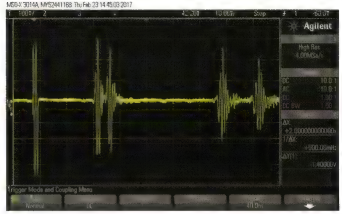


Fig.7: this shows the output of the reverb unit with a short 1kHz burst applied to the input. You can see the original pulse at the left side of the screen and the reverberating pulses, which have been mixed into the same audio signal, repeated twice with decaying amplitude.

tank and to the mixer; after being coupled across the 47nF capacitor, if passes through a second 220kΩ series resistor to also reach pin 6 of IC2b. So this is the point at which the original and reverberated signals meet and you can see how VR2 is used to vary the effect depth, as the louder the reverb signal is compared to the input signal, the more reverberation will be evident.

A third 220kΩ resistor provides feedback from IC2b's output pin 7 back to its inverting input, while the non-inverting input (pin 5) is connected to signal ground via a 75kΩ resistor. This value was chosen to be close to the value of three 220kΩ resistors in parallel, so the source impedance of both inputs is similar. IC2b operates as a "virtual earth" mixer, with both its input pins 5 and 6 held at signal ground potential.

Remember that the action of an op amp is to drive its output positive if the positive input is higher than the negative input and negative if the situation is reversed. So the feedback from its output to its inverting input operates to keep both inputs at the same potential. Since the non-inverting input is connected to ground, the inverting input will be held at that same potential and the signals represented by the currents flowing through the three 220kΩ resistors are mixed and appear as an inverted voltage at the output.

The output of IC2b is fed to output RCA connector CON4 via a 22µF AC-coupling capacitor and 100Ω short circuit protection/stabilisation resistor. The capacitor removes the DC bias from the output when a DC power supply is used. If an AC supply is used, the output of IC2b will already swing around 0V so no DC-blocking capacitor is needed and it is linked out.

Note that the PCB has provision for two back-to-back electrolytics here (for use with an AC supply). However, IC2b's output offset should be low enough that most equipment that would follow the reverb unit (eg, an amplifier) should not be upset by it, hence we are not recommending that you fit them.

Power supply

Two different configurations for the power supply are shown in Fig.3 and you can choose one or the other depending on which components you fit. The one at top suits a transformer of 9-15VAC (or 18-30VAC centre tapped). AC plugpacks can be used. The power supply configuration at bottom is intended for use with 12V batteries or DC plugpacks and will run off 12-15V DC, however, it could easily be adapted to handle higher DC voltages of up to 30V if necessary.

Looking at the AC configuration at top, the transformer is normally wired to CON5. If it isn't centre tapped, the connection is between pin 2 and either pin 1 or pin 3. For tapped transformers, the output is full-wave rectified by bridge rectifier BR1 while for single windings, the output is half-wave rectified. The output from BR1 is then fed to two 1000µF filter capacitors and on to linear regulators REG1 and REG2, to produce the ±15V rails.

If your AC supply is much lower than 15V (or 30V centre tapped), you will need to substitute 78L12/79L12 regulators for REG1 and REG2 to prevent ripple from feeding through to the output. Similarly, for AC supplies below 12V (or 24V centre tapped), use 78L09/79L09 regulators.

Assuming the reverb effect is on, switch pole S1c will be in the position shown and so the LED within S1 will be lit, with around 9.3mA [(30V - 2V) ÷ 3kΩ] passing through it.

Op amp stage IC1b is not used with an AC supply and so its non-inverting input is connected to ground and its output to its inverting input, preventing it from oscillating or otherwise misbehaving. With an AC supply, the signal ground is connected directly to the main (power) ground via a link.

DC supply

For a DC supply, such as a 12V battery, the configuration at bottom is used. Power can be fed in via terminal block CON5 or barrel connector CON6. If CON5 is fitted, it only needs to be a 2-way terminal block (although a 3-way block can still be fitted if desired). Diode D5 replaces the bridge rectifier and provides reverse polarity protection.

The main filter capacitor is larger, at 2200uF, to minimise supply ripple.

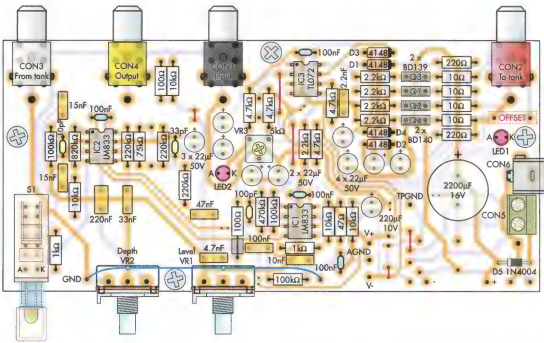


Fig.8(a): PCB overlay to suit a DC power supply. Don't forget to fit the five wire links where shown in red. You can fit either CON5, CON6 or both and CON5 can be a two-way or three-way terminal block.

For DC supply voltages above 15V, substitute a similarly-sized capacitor with a higher voltage rating such as 2200uF/25V or 1000uF/50V.

The current limiting resistor for LED3 has been reduced to 1kΩ so that it is still sufficiently bright with the reduced supply voltage while IC1b is configured to generate a virtual earth at half supply. This is derived from the main supply via a 10kΩ/10kΩ resistive divider with a 220µF capacitor across the bottom leg to eliminate supply ripple from the signal ground.

Op amp IC1b is configured as a buffer, so that the signal ground has a low impedance and drives it via a 47Ω resistor, to ensure op amp stability.

A 100nF capacitor between signal ground and power ground keeps the high-frequency impedance of the signal ground low despite this resistor.

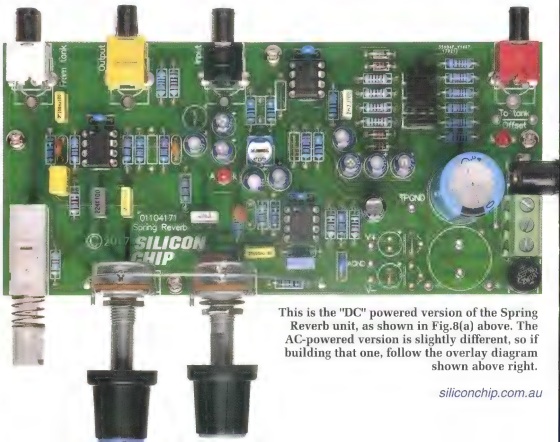
PCB construction

Assembly of the PCB is straightforward. It is coded 01104171 and measures 142 x 66mm with tracks on both sides, and plated through-holes. Two overlay diagrams are shown above: Fig.8(a) shows the component layout for a DC supply while Fig.8(b) shows the layout for an AC supply. Differences between the two will be noted in the following instructions.

Begin by fitting small signal diodes D1-D4, orientated as shown in Fig.8 and then use the lead off-cuts to form the wire links, shown in red. Both versions require five links to be fitted but some of them are in different places so follow the appropriate overlay diagram.

Next, fit the resistors where shown. While their colour code values are shown in the table overleaf, it's a good idea to check the resistor values with a multimeter before fitting them and remember to slip a ferrite bead over the lead of the 100Ω resistor just above VR1.

The resistors fitted to both versions are almost identical; besides the variation in value of the resistor next to S1, the only other difference is that the three resistors to the right of IC1 are



This is the "DC" powered version of the Spring Reverb unit, as shown in Fig.8(a) above. The AC-powered version is slightly different, so if building that one, follow the overlay diagram shown above right.

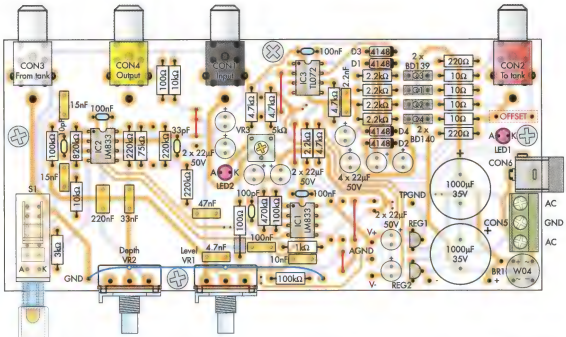


Fig.8(b): PCB overlay to suit an AC power supply. Don't forget to fit the five wire links where shown in red. Depending on the AC supply voltage, REG1/ REG2 should be either 7809/7909, 7812/7912 or 7815/7915 regulators; see text.

not fitted for the AC supply version.

For the DC supply version, you can now fit D5, orientated as shown.

If you are using IC sockets, solder them in place now, with the notched ends towards the top of the board. Otherwise, solder the three op amp ICs directly to the board with that same orientation. Note that IC3 is a TL072 while the other two ICs are LM833s so don't get them swapped around.

For the AC supply version, solder BR1 in place with its longer (+) lead towards upper left, as shown in Fig.8.

Now proceed to install the two onboard red LEDs (LED1 & LED2) with the longer anode leads to the left (marked A on the PCB) and all the ceramic and MKT capacitors in the locations shown in the overlay diagram. Polarity is not important for any of these capacitors.

Note that LED1 and LED2 are lit as long as power is applied so you could mount one of these off-board as a power-on indicator if necessary.

However, we think in most cases, constructors will be building the Reverb unit into an amplifier which already has a power-on indicator so this should be unnecessary and LED1/ LED2 can simply be mounted on the PCB as shown.

If you're building the AC-powered version, solder REG1 and REG2 in place now, orientated as shown. Don't get them mixed up. You will probably need to crank out their leads slightly using small pliers, to suit the PCB pads.

Now fit trimpot VR3, followed by illuminated switch S1. Make sure S1 is pushed all the way down onto the PCB before soldering two diagonally opposite pins and then check it's straight before soldering the remaining pins.

You can now install the small (22µF) electrolytic capacitors. These are polarised and the longer (+) lead must go towards the top of the board in each case, as shown using + symbols in Fig.8. If building the DC-powered version, there is also one 220µF capacitor that you can fit at the same time but make sure it goes in the position indicated.

Next, mount CON5 and/or CON6, depending on how you plan to wire up the power supply. If fitting CON5, make sure its wire entry holes go towards the nearest edge of the board and if using a 2-way connector (for a DC supply), make sure it goes in the top two holes as shown in Fig.8(a).

Next, fit CON1-CON4. In each case, you have a choice of using either a horizontal switched RCA socket (as shown on our prototype) or a vertical RCA socket fitted either to the top or the bottom of the PCB.

Pads are provided for all three possibilities and which is best depends on how you're planning on running the wiring in your particular amplifier.

As you will see later, we recommend using a stereo RCA-RCA lead to connect the main board to the tank, and the tank will normally be mounted in the bottom of the amplifier chassis while the Reverb board will normally be mounted on the front panel. So keep that in mind when deciding which RCA socket configuration to use.

If you want to fit PCB pins for the test points, do so now, however it isn't really necessary since the pads are quite easy to probe with standard DMM leads.

Transistors Q1-Q4 should be fitted next. Don't get the two types mixed up; the BD139s go towards the top of the board while the two BD140s go below. All four transistors are fitted with their metal tabs facing towards the bottom of the board as shown; if you're unsure, check the lead photo.

You can now solder the large electrolytic capacitor(s) in place; the DC supply version has one, located as shown in Fig.8(a) while the AC supply version has two. In all cases, the longer (+) lead goes towards the top of the board as shown.

The last components to fit to the PCB are potentiometers VR1 and VR2, however, before installing them you must do two things. Firstly, clamp each pot in a vice and file off a small area of passivation on the top of the body, allowing you to solder the ground wire later on.

And secondly, figure out how long you need the shafts to be to suit your amplifier and cut them to length. Make sure they're still long enough so that you can fit the knobs later!

Now solder the two pots to the board, ensuring that the 10kΩ pot

Parts list – Spring Reverb Unit

1 double-sided PCB, coded 01104171, 142 x 66mm
1 spring reverb tank (see text)
1 stereo RCA lead with separate shield wires
4 RCA sockets, switched horizontal or vertical (CON1-CON4)
1 3-way terminal block, 5.08mm pitch (CON5) OR
1 PCB-mount DC socket, 2.1mm or 2.5mm ID (CON6)
1 50kΩ logarithmic taper single-gang 16mm potentiometer (VR1)
1 10kΩ logarithmic taper single-gang 16mm potentiometer (VR2)
1 5kΩ mini horizontal trimpot (VR3)
2 knobs to suit VR1 and VR2
1 4PDT push-push latching switch with integral LED (S1) (Altronics S1450 [red LED], S1451 [green LED] or S1452 [yellow LED])
8 PCB pins (optional)
1 100mm length 0.7mm diameter tinned copper wire
3 8-pin DIL sockets (IC1-IC3) (optional)

Semiconductors

2 LM833 low noise dual op amps (IC1,IC2)
1 TL072 low noise JFET-input dual op amp (IC3)
2 BD135/137/139 1.5A NPN transistors (Q1,Q3)
2 BD136/138/140 1.5A PNP transistors (Q2,Q4)
2 red 3mm LEDs (LED1,LED2)
4 1N4148 signal diodes (D1-D4)

Capacitors

10 22μF 50V electrolytic
1 220nF 63/100V MKT
2 100nF 63/100V MKT
3 100nF multi-layer ceramic
1 47nF 63/100V MKT
1 33nF 63/100V MKT
1 15nF 63/100V MKT
1 10nF 63/100V MKT
1 4.7nF 63/100V MKT
1 2.2nF 63/100V MKT
1 100pF ceramic
1 33pF ceramic
1 10pF ceramic

Resistors (all 0.25W, 1%)

1 820kΩ	1 470kΩ	3 220kΩ	3 100kΩ	1 75kΩ	2 10kΩ
4 4.7kΩ	6 2.2kΩ	1 1kΩ	2 220Ω	2 100Ω	4 10Ω

Additional parts for 9-15VAC powered version

1 78L09, 78L12 or 78L15 positive 100mA regulator (REG1) (see text)
1 78L09, 79L12 or 79L15 negative 100mA regulator (REG2) (see text)
1 W02/W04 1A bridge rectifier (BR1)
2 1000μF 35V/50V electrolytic capacitors, 16mm maximum diameter, 7.5mm lead spacing
1 22μF 50V electrolytic capacitor
1 3kΩ 0.25W 1% resistor

Additional parts for 12-15V DC powered version

1 1N4004 1A diode (D5)
1 2200μF 16V electrolytic capacitors, 16mm maximum diameter, 7.5mm lead spacing
1 220μF 10V electrolytic capacitor
1 100nF multi-layer ceramic capacitor
2 10kΩ 0.25W 1% resistors
1 1kΩ 0.25W 1% resistor
1 47Ω 0.25W 1% resistor

(VR2) goes on the left side and then insert one end of a 100mm length of tinned copper wire in the pad marked "GND", just to the left of VR2, and solder it in place. Now bend the wire so it contacts the top of the two pot bodies and then solder it to the free pad to the right, as shown in Fig.8, and trim off the excess.

Now it's just a matter of soldering this ground wire to the areas where you scraped away the passivation from VR1 and VR2. Note that you will need to apply the soldering iron for a few seconds for the metal to get hot enough for solder to adhere.

Testing and set-up

The first step is to apply power and check the supply voltages. If you've fitted sockets, leave the ICs off the board for the time being. Having said that, if you have configured the board for a DC supply, plug in LM833 op amp IC1 (taking care with its orientation).

Apply power and check that the voltages at the five specified test points are close to the values given in Table 1 (on the circuit diagram).

Voltage variation on the "+" and "-" test points can be expected to be fairly large, possibly a couple of volts either side of those given. Voltages at V+ and V- should be within about 250mV of the optimal values while, for DC supplies, the voltage at AGND should be almost exactly half that at V+.

If you've fitted sockets, cut power and plug in the remaining ICs. Don't get IC3 (TL072) mixed up with the other two ICs which are LM833s. In each case, the pin 1 dot must go towards the top edge of the PCB, as shown in Fig.8. Re-apply power for the remaining steps.

Measure the voltage between the two test points labelled "OFFSET" in the upper-right corner of the PCB. You should get a reading below 100mV. If not, switch off and check for soldering problems or incorrect components around IC3a and IC3b. Assuming the reading is low, slowly rotate trimpot VR3 and check that you can adjust it near zero. It should be possible to get the reading well under 1mV.

If you have appropriate cables or adaptors, you can now do a live signal test. Use a stereo RCA/RCA or RCA/3.5mm-plug cable to connect a mobile phone, MP3 player or other signal source to CON1. Turn VR1 and VR2 fully anti-clockwise. Use a

cable with RCA plugs at one end and a 3.5mm stereo socket at the other end to connect a pair of headphones or earphones with a nominal impedance of at least 16Ω (ideally 32Ω or more) to CON4.

Power up the board, start the signal source and slowly advance VR1. You should hear the audio signal passing through the unit undistorted.

Now you can use a stereo RCA/RCA lead to connect the main board to the tank, via CON2 and CON3, matching up the labels on the board with those on the tank. The tank should be placed on a level surface with the open part facing down. Continue listening to the signal source, then advance VR2. You should hear the reverb effect. If you're unsure, pause the audio source and you should continue to hear audio for several seconds until the reverb dies out.

That's it – the Spring Reverb unit is fully functional.

Installation

The tank should be installed with the open end down because the spring suspension is designed to work optimally in that position. Use the four corner holes to mount it since the tank is microphonic and these are designed to provide some isolation to prevent bumps from upsetting the springs too much. It would probably be a good idea to add extra rubber grommets under each spacer and avoid compressing them too much, for extra isolation.

As for mounting the PCB, you have three options. Option one is to mount it somewhere on the front panel of the amplifier so that switch S1 and potentiometers VR1 and VR2 are easily accessible. You then simply connect it to the tank using a stereo RCA/RCA lead.

If the panel it's mounted on is thin enough, it can be held in place using the two potentiometer nuts, although it would be a good idea to attach a small right-angle bracket to the mounting hole between the two pots, on the underside of the board via an insulating spacer, to provide a third anchor point on the panel.

The second possibility is to fashion a bracket from a sheet of aluminium with four holes drilled in it, matching the mounting holes in the board, with the side near the front of the board bent down and additional holes drilled in this flange for attachment to the front panel of the amp. You can then use self-tapping or machine screws to attach this bracket to the amp and then the board to the bracket. For bonus points, earth the aluminium bracket back to the GND pad on the PCB, to provide some shielding.

There are no controls on the spring reverb tank itself, just an input (red) and output (white) RCA socket. All controls are on the PCB for this project.

The third possibility is to leave S1, VR1 and VR2 off the board and mount it on top of the tank itself. We suggest using a long insulating spacer attached to one of the free holes on the tank's flange, supporting the PCB via the front or rear mounting hole, with a liberal application of thick double-sided foam tape on top of the tank to support the PCB.

You will need to trim the component leads carefully to make sure they can't poke through the foam tape and short on the top of the tank. In fact, it would be a good idea to silicone a sheet of plastic on top of the tank before applying the tape to provide extra insulation.

You would then mount S1, VR1 and VR2 wherever suitable and connect them back to the board using twin-core shielded cable for VR1 and VR2 (with the shield to the left-mount [ground] pin in each case). For the connections to S1, use regular shielded cable with the shield wired to the pin connected to ground and the central conductor for the audio pin, and a section of ribbon cable for the LED connections.

Using it

Using it is straightforward. Push S1 in to enable reverb and push it again so it pops out to disable reverb. When reverb is enabled, S1 will light.

Adjust VR1 to give a near-maximum output level without clipping and then tweak VR2 until you get the desired reverberation effect.

With VR2 fully clockwise, the effect is overwhelming; you will probably find it most useful somewhere between 10 o'clock and 2 o'clock. SC

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	820kΩ	grey red yellow brown	grey red black orange brown
❑	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❑	3	220kΩ	red red yellow brown	red red black orange brown
❑	3	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	75kΩ	violet green orange brown	violet green black red brown
❑	2*	10kΩ	brown black orange brown	brown black black red brown
❑	4	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	6	2.2kΩ	red red red brown	red red black brown brown
❑	1#	1kΩ	brown black red brown	brown black black brown brown
❑	2	220Ω	red red brown brown	red red black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown
❑	4	10Ω	brown black black brown	brown black black gold brown
❑	1^	3.0kΩ	orange black red brown	orange black black brown brown
❑	1‡	47Ω	yellow violet brown brown	yellow violet black gold brown

* 4 required for DC supply version # 2 required for DC supply version
^ only required for AC supply version ‡ only required for DC supply version

Build the eFuse

*** A Resettable Circuit Breaker * Ideal for automotive fault-finding * Set for any current between 315mA and 10A**

This resettable Electronic Fuse (eFuse) can be used temporarily in place of a conventional fuse when fault-finding. It is ideal when tracking down the cause of a blown fuse. The eFuse acts like a circuit breaker, automatically disconnecting power a short time after the current through it exceeds a set value. If it "trips out", just press the reset button to get the current flowing again!

When you have blown a fuse for the nth time and you really don't know why, how often have you wished you could press a button and have the fuse "repair" itself? Well, with the eFuse, now you can!

If, for example, you are trying to find out why fuses keep blowing in a car, van or trailer, you have two ways to check them: keep blowing fuses until you track down the problem (and end up with a pocket full of blown fuses) . . . **or** you can use the SILICON CHIP eFuse to save time and frustration.

Mind you, the eFuse is not just limited to automotive applications: it can be used when trouble-shooting *any* circuit which runs at DC voltages between 9V & 15V.

Three LED indicators show when there is voltage present at the eFuse input and output, and also whether it has tripped.

In use, the eFuse is connected in place of the conventional fuse by being plugged into the fuseholder of the circuit under investigation (only suitable for vehicles or circuits that have the fuse in the positive supply line).

You can set up the eFuse for a trip current that includes standard fuse ratings between 315mA and 10A.

Points to consider

Note that the eFuse does draw a slight amount of current when it is connected in-circuit, on top of that consumed by the load itself.

This amounts to around 15mA and is mostly due to the indicator LEDs. If you really concerned by the "fuse current", you could remove the power indicator LEDs (or use high-brightness LEDs with much higher current limiting LEDs) but there still will be around 1.7mA drawn by the eFuse itself.

Also the eFuse has a voltage loss that may be a little higher than that of a typical high-current fuse but that should not cause a problem in most circuits.

The voltage drop is typically around 0.4V at 10A and proportionally less at lower currents.

Configuration

The eFuse is housed in a small plastic box with three indicator LEDs, a pushbutton reset switch and a conventional fuse on the front panel.

It has three leads, two for connection to the fuseholder (to replace the conventional fuse) while the third lead is to connect to chassis, which provides the negative supply for the eFuse.

The positive supply for the eFuse comes from the connection to the fuseholder.

A conventional fuse is included in the eFuse just as a safeguard. It would only blow if the eFuse itself fails.

Table 1 shows the LED indications under various conditions. If LEDs 1 & 3 are alight, the eFuse is conducting. If LED2 lights, the eFuse has gone "open circuit".

In this case, LED3 will generally be off although it may glow dimly if the load is disconnected. You can press the Reset

By JOHN CLARKE

Features

* Adjustable trip current
* Reset switch
* LED lights when tripped
* Capable of withstanding brief overloads
* Reverse connection protection
* Indication of input and output voltage presence
* Transient voltage protection
* Output voltage clamping
* Onboard safeguard fuse

switch after the eFuse has "blown", to reconnect power to the load.

eFuse operation

The eFuse operates somewhat like conventional fast-blow fuse. Conventional fuses come in several different types including standard, fast and slow blow. Typically, a standard fuse requires twice its rated current to open in one second, a fast-blow fuse requires twice its rated current to blow in 100ms, and a slow-blow fuse requires twice its rated current to blow after tens of seconds.

The eFuse operates by limiting the current passing through it and it has two current limits. One is the short-circuit current limit and the other is the overload current limit. The overload limit is higher than the short-circuit limit.

As long as the current flow through the eFuse remains below the overload limit, it operates in full conduction. However, should the overload limit be exceeded, current through the eFuse is limited to the lower short-circuit limit. If the eFuse output is shorted, this will happen almost instantaneously and it will be as if the current was limited to the short-circuit level initially.

While the current is being limited in this manner, the eFuse IC heats up and one of two things can happen: it trips off, disconnecting the load or if the overload condition is cleared (eg, output short removed), the eFuse goes back to full conduction.

The time it takes the eFuse to "blow" typically ranges from 1-100ms, depending mainly on the current limit setting.

The two current limits cannot be set separately; they're locked together. You set the short-circuit current limit and the overload current limit is automatically set to a somewhat higher value.

Typically, you would set the short-circuit current limit to the same value as you would select for a standard fast-blow fuse in the circuit being protected.

If you're confused about the two different current limits, think of the difference in the two limits as similar to hysteresis in the comparator which compares the current flow to a reference current limit.

It also serves to allow the load to draw more than the rated

Table 1: LED Indicator states

eFuse state	Supply indicator (LED1)	Output indicator (LED3)	Trip indicator (LED2)
Normal	Lit	Lit	Off
Limiting	Lit	Dimmed	Off
Tripped	Lit	Off or dim	Lit
Reversed supply/ output connection	Off	Lit	Off

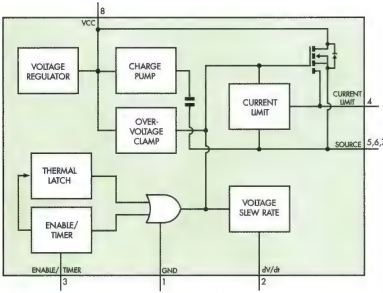


Fig.1: the block diagram of the NIS5112 is shows the SenseFET in the top righthand corner. The charge pump circuit provides the necessary voltage-shifted gate signal to the SenseFET for high-side switching. However, the coupling from the charge pump to the SenseFET gate is not shown.

current for brief periods, eg, while charging up capacitors (which a normal fuse would also tolerate).

The eFuse cannot be reset to restore power until the overload or short-circuit has been removed. Depending on how soon you reset it, the overload current limit may be lower than it was initially, until the eFuse IC cools down.

The current limiting described above not only provides the fuse function but also serves to protect the eFuse itself.

Current sensing

The main component in the eFuse is an NIS5112 Electronic Fuse IC manufactured by ON Semiconductor. Its internal function block diagram is shown in Fig.1.

It contains an internal N-channel Mosfet which conducts current from the V_{CC} supply at pin 8 to output Source pins 5, 6 & 7. This Mosfet has a typical on-resistance of 30mΩ, current ratings of 5.3A continuous and 25A peak and is a current-sensing type, known as a "SenseFET". This consists of two Mosfets in parallel, one of which is much bigger than the other.

Most of the current flows through the bigger Mosfet and the ratio of the currents flowing through the two Mosfets is constant. A small resistor connected in series with the smaller Mosfet allows the total current to be sensed, without needing to pass the full current through this resistor.

To explain the benefit of a SenseFET, consider the conventional method for sensing current through a Mosfet, as shown in Fig.2(a). The problem with this approach is that since the entire load current flows through the sense resistor, it must have a very low value and high power rating to avoid excessive dissipation, reduced efficiency and overheating. This results in a small voltage which typically must be amplified before being fed to a microcontroller or analog-to-digital converter and the amplification inevitably increases the noise level in the current reading.

The configuration of a SenseFET is shown in Fig.2(b). In this case, some small proportion (say 1%) of the current always flows through the smaller FET while the other 99% flows through the larger FET. The drain current and gate voltage is therefore the same as with a regular FET, but this current is split between the two source terminals. This allows a resistor to be inserted in series with the smaller FET such that 1% of the load current (say) flows through it while the other 99% flows unimpeded. This is shown in Fig.2(c).

Since the current through this resistor is so low, say 100mA when the total current is 10A (ie, 10A x 1%), it can have a much higher value, so the sense voltage is higher and there is no need to amplify it. Also, despite the higher voltage across this resistor, the dissipation is much, much lower and there's no need to use a high power resistor.

In practice, in the eFuse circuit, the current sense resistor has a value of 20Ω or more, dissipation is very low, under 100μW (0.1mW) and the ratio of the two currents is 1000:1 (ie, 99.9% and 0.1%).

Electronic fuse IC details

Being an N-channel device, the internal Mosfet (SenseFET) needs a gate voltage higher than V_{CC} to operate as a high-side switch and so the IC has an internal charge pump to generate this voltage.

The NIS5112 also includes a soft-start feature whereby a capacitor connected to the dV/dt input (pin 2) is charged from a current source, causing the Mosfet to gradually switch on at power up. dV/dt simply refers to the rate of voltage change (dV) with time (dt). The slow start-up rate is useful when the load would normally have a high initial surge current. This includes loads that have large filter capacitors or capacitor banks across their inputs.

The slow start allows these capacitor(s) to charge without tripping the eFuse. The same slow start-up procedure applies when the eFuse is reset.

Fuse tripping is handled by monitoring the Mosfet temperature and the IC switches it off quickly when the die

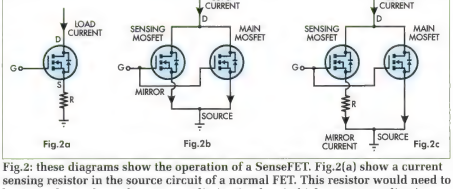


Fig.2: these diagrams show the operation of a SenseFET. Fig.2(a) show a current sensing resistor in the source circuit of a normal FET. This resistor would need to be a very low value to keep power dissipation low in high current applications. A SenseFET has two FETs with the smaller FET "mirroring" the current in the main FET (Fig.2(b)). So the sensing FET can have a much higher value of sensing resistor without consequent high power dissipation, as in Fig.2(c).

temperature reaches about 135°C. There are two versions of the NIS5112 which differ in regards to how tripping is handled. In one version, the Mosfet stays off once it is tripped until reset and this is the version we are using. The other version restores fuse operation automatically when the temperature drops below 95°C.

Another feature of the NIS5112 is over-voltage clamping which limits the output voltage to 15V. Clamping is done by controlling gate drive to the Mosfet to adjust the drain-source resistance to maintain the 15V maximum output. Note though that if the input voltage is very far above 15V and stays that way for a significant time, the Mosfet is likely to overheat and trip the fuse.

SPECIFICATIONS

Supply voltage: 9-15V
Polarity: ..... for fuses connected in series with the positive supply line
Current drain: ..... 15mA typical (1.7mA with LED1 and LED3 removed)
Trip current range: .. See Table 1
Trip response time: . typically 10ms
Overload current: .....13.6A (with two fuse ICs fitted; self-limiting)
Supply voltage: ..... 15V maximum

Paralleling eFuse ICs

Typically, if two NIS5112 ICs are connected in parallel, they will automatically current share the current, ie, 50% of the overall current is carried in the Mosfet within each IC. Thus, the actual trip level will be twice the set trip level for each IC. The reason is as follows.

At 25°C, the internal Mosfets in IC1 and IC2 have an on-resistance of around 28mΩ. If one Mosfet has a slightly lower on-resistance, it will conduct more current and so heat up a little more than its companion. Mosfet on-resistance rises with temperature (to around 37mΩ at 100°C) and the increased resistance will reduce the current through this Mosfet so more current flows through the other Mosfet. The Mosfets will stabilise in temperature as each Mosfet shares current more or less equally.

It may not be obvious that the Mosfet with the lower on-resistance will heat up more since the resistance is one factor in calculation the dissipation, but note that the equation is I^2R and since the current will increase proportionally as the on-resistance decreases, the fact that the current is squared in this equation means that its increase will more than compensate from the reduction in dissipation due to lower resistance.

One small wrinkle when paralleling NIS5112 ICs is that while they will share current before either trips, inevitably one will trip before the other (due to differences in on-resistance, external resistor value, temperature sensor accuracy etc), leaving the remaining IC to continue passing the full load current for a brief period.

Before this second IC trips, it will continue to limit the current to one half the value compared to when the two ICs were conducting. However, normally the second IC will trip very soon after the first due to the increased dissipation in this condition so it isn't really an issue.

Circuit description

The circuit for the SILICON CHIP eFuse is shown in Fig.3 and it can use one or two NIS5112 electronic fuse ICs. With a single IC fitted, the eFuse will work up to 5A whereas with two, you can set the trip current as high as 10A.

Resistors R1 and R2 set the trip current for IC1 and IC2

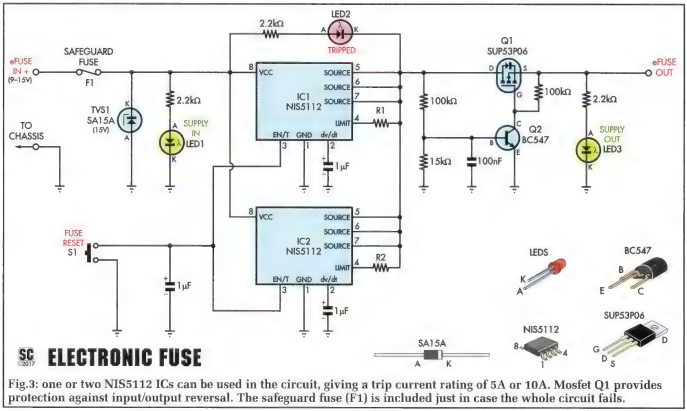
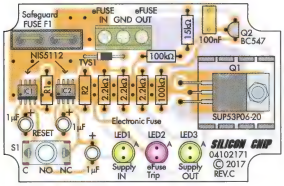


Fig.3: one or two NIS5112 ICs can be used in the circuit, giving a trip current rating of 5A or 10A. Mosfet Q1 provides protection against input/output reversal. The safeguard fuse (F1) is included just in case the whole circuit fails.



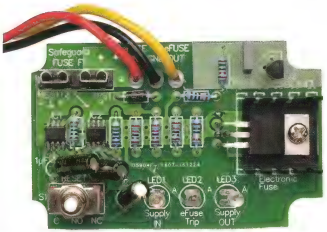


Fig.4: the safeguard fuse is a standard automotive blade type, mounted on the top left corner of the PCB. The external connections can be made via a 3-way terminal block, as shown on the component overlay at left, or wired directly, as shown in the photo at right.

respectively. Assuming both ICs are fitted, both resistors must be the same value so the trip current is the same for each. Table 2 shows the various trip currents that can be selected with one IC fitted while Table 3 shows the values for R1 & R2 with IC1 & IC2 fitted.

Note that for a given short-circuit trip current ratings, there will difference in the overload current rating, depending on whether you use one or two ICs. For example, a 3A eFuse with just IC1 fitted has an overload rating of 4.6A but with IC1 and IC2 fitted, has an overload rating of 7.6A instead. So fitting both ICs is to be preferred since a normal fuse will typically handle overloads up to twice its rated current (ie, 6A in this case) for around one minute before blowing.

The dV/dt inputs for IC1 and IC2 (pin 2) each connect to a 1µF capacitor so that after resetting or during power up, the eFuse output will slowly rise in voltage to supply the load over about 80ms, ie, it "slew rate" limits. A second 1µF capacitor across reset switch S1 provides a slight delay after resetting and serves as a contact de-bounce for the switch.

The input supply indicator, LED1, lights whenever power is connected to the eFuse. LED2 lights when the eFuse trips and LED3 lights when there is a supply to the load.

Circuit protection

Note that the output from IC1 (and IC2 if used) passes current to the eFuse output via P-channel Mosfet Q1. This Mosfet provides reverse connection protection (ie, if power is incorrectly applied to the eFuse output rather than its input). While we could have used a schottky diode to provide the same reverse polarity protection, its forward voltage drop of about 0.5V at 10A, is much higher than the conduction voltage of Q1.

It works as follows. Once IC1/IC2 switch on, the output voltage turns on NPN transistor Q2 via a 100kΩ/15kΩ resistive divider and current limiting network. Q2 pulls the gate of Q1 low, switching it on. It will have started conducting current to the load anyway, via its body diode, however this has a high forward voltage drop and that diode is effectively shorted out once the Mosfet switches on, so only its low on-resistance of around 20mΩ affects the load voltage slightly.

If the circuit is connected in reverse, with a voltage source connected to the output, Q1's body diode is reverse-biased so will not conduct and since its gate pin is pulled up by the 100kΩ resistor from its source, it will remain switched off. The 100nF capacitor and 15kΩ resistor across Q2's base-emitter junction ensures that it too remains off, despite any voltage coupled across Q1's gate/source or drain/source capacitance. This condition is indicated by LED3 being lit while LED1 is off so you can easily identify and rectify it.

Q1 also protects the circuit if the connections are swapped both in terms of input/output and also polarity; ie, if the "eFuse out" terminal is connected to 0V and 0V

Table 2: Only IC1 installed

Short Circuit Trip Current	Overload Current	Safeguard Fuse rating	R1
315mA	3.5A	1A	430Ω
350mA	3.5A	1A	390Ω
500mA	3.6A	1A	330Ω
800mA	3.7A	1A	180Ω
1A	3.8A	1A	120Ω
1.6A	3.9A	2A	91Ω
2A	4.1A	2A	62Ω
2.5A	4.5A	3A	47Ω
3A	4.6A	3A	39Ω
3.15A	4.6A	3A	36Ω
4A	5.5	5A	27Ω
5A	6.8A	5A	20Ω

Table 3: IC1 and IC2 installed

Short Circuit Trip Current	Overload Current	Safeguard Fuse rating	R1 & R2 (IC2 installed)
800mA	7A	1A	360Ω
1A	7.2A	1A	330Ω
1.25A	3.9A	1A	220Ω
2A	7A	2A	150Ω
2.5A	7.2A	3A	120Ω
3A	7.6A	3A	91Ω
3.15A	7.7A	3A	82Ω
4A	8.2A	5A	62Ω
5A	8.4A	5A	43Ω
6.5A	9.2A	7.5A	36Ω
7.5A	10.6A	10A	30Ω
10A	13.6A	10A	20Ω

terminal to +15V, little current will flow and no damage will result. However, if the input is connected with reverse polarity – ie, with "eFuse in" to 0V and the 0V terminal to +15V, TVS1 will conduct a large amount of current and safeguard fuse F1 will blow.

In normal use, with the correct supply polarity, TVS1 is used to clamp transient voltages over about 18V and thus to protect IC1 and IC2 from over-voltage damage. As well as protecting against reverse polarity, F1 prevents further damage in the case of any other catastrophic faults.

Construction

The eFuse is built on a PCB coded 04102171 and measuring 74 x 47mm. It can be housed in a small plastic box measuring 83 x 54 x 31mm. A panel label measuring 78 x 48mm can also be glued to the base of the box which is normally fitted with a cable gland at one end for the wires to pass through.

Before starting construction, decide on the current rating you require and whether or not to install both IC1 and IC2. If you only install IC1, use Table 2 to select the value of R1. If you install both IC1 & IC2, select R1 & R2 from Table 3.

Use the overlay diagram, Fig.4, as an assembly guide. IC1 (and IC2 if used) are installed first. Start by aligning pin 1 of the IC on the marking on the PCB. Solder pin 1 first, then check that the IC pins are correctly aligned. If not oriented correctly, re-melt the solder and adjust placement until the IC is correctly positioned.

Finally, solder the remaining pins and refresh the initially tacked pin. Any solder bridges between the pins can be removed with solder wick. Note that pins 5, 6 and 7 are meant to be connected together.

Install the resistors next and then TVS1. The resistors are colour coded with the resistance value and the table overleaf shows the colour bands for each resistor used. A digital multimeter should also be used to check the values as the colour bands can be hard to identify. Make sure that TVS1 is installed with the correct polarity, with the striped end oriented as shown in the overlay diagram.

The P-channel Mosfet Q1 is fitted with a heatsink. Bend its leads over by 90° and insert them into the PCB holes, then secure both the Mosfet tab and heatsink using an M3 x 10mm screw and nut before soldering the leads.

Switch S1 is mounted next. We have arranged the PCB so that S1 can be oriented either way. Follow with the capacitors. The electrolytic types must be installed with the polarity shown, ie, longer lead through the holes marked +. These will need to be laid over sideways so they sit no taller than the switch body. Transistor Q2 can also be fitted now.

The LEDs are mounted with the top of each lens

Parts list – eFuse

1 double-sided PCB coded 04102171, 74 x 47mm
1 UB5 plastic box, 83 x 54 x31mm
1 panel label, 78 x 48mm
1 SPDT PCB-mount momentary pushbutton switch (Altronics S1393) (S1)
1 6073B-type flag heatsink, 19 x 19 x 10mm (Jaycar HH8502, Altronics H0630) (for Q1)
1 PCB-mount ATO/ATC blade fuse holder (Altronics S6040) (F1)
1 ATO/ATC blade fuse (see Table 2&3)
1 blown fuse (to connect eFuse to circuit being protected)
1 cable gland for 6mm diameter cable
1 M3 x 10mm machine screw and nut (to mount Q1)
1 crimp eyelet or alligator clip (for 0V lead)
1 1m length of light or medium-duty black insulated wire
1 1m length of red insulated wire, rated to suit eFuse configuration
1 1m length of yellow insulated wire, rated to suit eFuse configuration

Semiconductors
1 NIS5112D1R2G latch-off electronic fuse (IC1)
1 SUP53P06 P-channel Mosfet (Q1)
1 BC547 NPN transistor (Q2)
1 500W 15V Transient Voltage Suppressor (eg, SA15A) (TVS1)
2 3mm green LEDs (LED1 & LED3)
1 3mm red LED (LED2)

Capacitors
2 1µF 25V (or 63V) PC electrolytic
1 100nF 63V or 100V MKT polyester

Resistors (0.25W 1%)
2 100kΩ 1 15kΩ 3 2.2kΩ
plus R1 & R2 (see Table 2&3)

Additional parts if fitting IC2
1 NIS5112D1R2G latch-off electronic fuse (IC2)
1 1uF 25V or 63V PC electrolytic
1 0.25W 1% resistor for R2 (see Table 3)

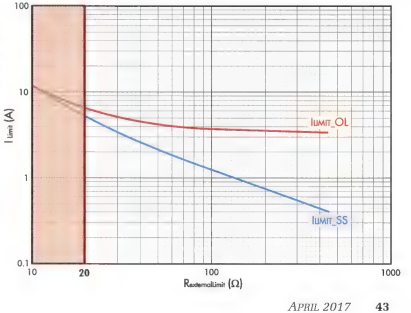


Fig.5: reproduced from the data sheet, this graph shows the short circuit and overload current limits of a single NIS5112 IC for various values of limiting resistor (ie, R1). Note that we have selected a minimum value of 20Ω, giving the device the ability to carry 5A continuously. Lower values of R1 will allow higher currents to be carried for short periods until it reaches its internal temperature limit and then trips out. So in fact, lower values for R1 are not practical.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	15kΩ	brown green orange brown	brown green black red brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	*	430Ω	yellow orange brown brown	yellow orange brown brown
❑	*	390Ω	orange white brown brown	orange white black blackbrown
❑	*	360Ω	orange blue brown brown	orange blue black black brown
❑	*	330Ω	orange orange black brown	orange orange black black brown
❑	*	220Ω	red red brown brown	red red black black brown
❑	*	180Ω	brown grey brown brown	brown grey black black brown
❑	*	150Ω	brown green brown brown	brown green black black brown
❑	*	120Ω	brown red brown brown	brown red black black brown
❑	*	91Ω	white brown black brown	white brown black gold brown
❑	*	82Ω	grey red black brown	grey red black gold brown
❑	*	62Ω	blue red black brown	blue red black gold brown
❑	*	47Ω	yellow purple black brown	yellow purple black gold brown
❑	*	43Ω	yellow orange black brown	yellow orange black gold brown
❑	*	39Ω	orange white black brown	orange white black gold brown
❑	*	36Ω	orange blue black brown	orange blue black gold brown
❑	*	30Ω	orange black black brown	orange black black gold brown
❑	*	27Ω	red purple black brown	red purple black gold brown
❑	*	20Ω	red black brown brown	red black black gold brown

** A selection of these resistors is used for R1 and/or R2 – see Table 2 and Table 3 for details.*

dome 17mm above the PCB surface. Make sure the LEDs are oriented correctly with the anode (longer lead) soldered to the pad marked "A".

The Supply In and Supply Out LEDs are green (LED1 and LED3) and the trip indicator (LED2) is red.

The input supply and output (load) wires can be soldered directly to the PCB or secured in a 3-way terminal block, as we show on the component overlay. We used red for the eFuse input, black for the 0V wire and yellow for the eFuse output wire.

Note that although the 0V wire carries little current, it's probably a good idea to use the same type of wire for all three connections.

The eFuse PCB is installed upside-down in the plastic case with the PCB clipped into the side flanges and the LEDs, switch and safeguard fuse protruding through the base.

A copy of the front panel artwork can also be used as a drilling diagram. Drill and file to shape the required holes for the LEDs, switch and fuse. You will also need to drill a hole for the cable gland, centred on the end of the box near to the safeguard fuse.

To produce a front panel label, you have a variety of choices available, ranging from "quick'n'easy" through to quite professional finishes.

These are discussed on the SILICON CHIP website at www.siliconchip.com.au/fp

Finishing it

The PCB can now be installed in the box. First, place a nut on the switch shaft and screw it down onto the switch body. Leave the safeguard fuse out of its fuseholder. Pass the wires through the gland and place the PCB into the box and make sure the LEDs and switch enter the holes.

Pull the wires through as you clip the PCB into place. Clamp down the cable gland over the wires and refit the safegard fuse.

The eFuse input and output wires can be soldered to either end of a blown fuse so it can be plugged into a fuseholder in the circuit being protected.

Blade fuses normally have exposed metal on the top of the fuse (presumably intended to allow you to probe the fuse while it's fitted) that can be used to solder the wires to.

If you don't have a blown fuse, you can create one by directly connecting a low-current fuse across a vehicle battery. Wear safety goggles when doing this.

Testing

Plug the fuse plug into the circuit to be protected and attach the negative lead to chassis with a clip or with a screw. Check that the supply in and supply out LEDs (LED1 and LED3 respectively) light. If only the supply out LED lights, the fuse is most likely connected in reverse. Table 3 shows the various LED indications.

Assuming they do both light, the eFuse is ready for action. SC

This same-size artwork can be copied and printed to make a label for the eFuse. Alternatively, you can download a PDF from www.siliconchip.com.au

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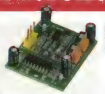

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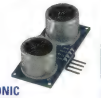
- Operating Voltage: 5VDC

$7.95



DUAL ULTRASONIC SENSOR MODULE XC-4442

The popular HC-SR04 ultrasonic distance module provides an easy way for your DuinoTECH to measure distances up to 4.5m.

- Uses two digital pins
- Operating Voltage: 5VDC

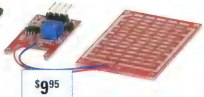
$9.95

OBSTACLE AVOIDANCE MODULE XC-4524

An inexpensive solution for an IR obstacle avoidance sensor, perfect for robotic projects with easy interface with Arduino® & compatible boards.

- Adjustable frequency and intensity
- 4 pin header
- Operating voltage: 5VDC

$9.95



RAIN SENSOR MODULE XC-4603

This sensor will detect contact from any conductive object, not just rain, so it could be used for as a large touch sensor panel as well as letting you know when it's raining.

- Operating Voltage: 5VDC

$19.95

RFID READ AND WRITE KIT XC-4506

Allows you to both read and write MiFare-Type RFID cards and create your own contactless security lock. Includes one credit-card style tag and one key-fob style tag.

- Communications Protocol: SPI
- Includes 2 tags (1 card, one fob)
- Operating Voltage: 3.3V

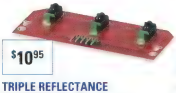
$9.95

TEMPERATURE AND HUMIDITY SENSOR MODULE XC-4520

Measure both temperature and humidity. Fully digital operated so no analogue-to-digital calibration is required.

- Temperature Range: 0 °C - 50 °C +/- 2 °C
- Humidity Range: 20 – 80% +/- 5%
- Sample Rate: 1Hz
- Operating Voltage: 3-5VDC

$10.95



TRIPLE REFLECTANCE SENSOR MODULE XC-4611

Create a smarter line-following robot with the Triple Infrared Reflectance Sensor Module. The module has three evenly spaced sensors and mounting holes.

- CTRT5000 sensor IC
- Only 2 pins needed for power / 3 for outputs
- Operating voltage: 5VDC

$37.95

ULTRAVIOLET SENSOR MODULE XC-4518

Can be used to measure UV exposure from the sun, or even check that your UV steriliser or EPROM eraser are working correctly.

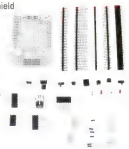
- Response wavelength 200-370nm
- Operating Voltage: 3-5VDC

ARDUINO® COMPATIBLE MODULE & SHIELD KITS

PROTO SHIELD KIT XC-4555

Build your own Arduino® shield using the compact and flexible Proto Shield kit. Solder together a range of circuits and reuse it in all your Arduino® projects. Kit includes multiple headers, resistors and spacers.

See online for more information.

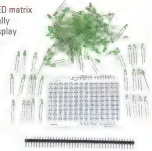


$19.95

LOL SHIELD KIT XC-4546

The Lol_Shield is a charlieplexed LED matrix for the Arduino®. LEDs are individually addressable so you can use it to display anything in a 9 x 14 grid. Scroll text, play games or display images, you can choose to use the Lol_Shield Library or program the animation manually.

- 126 individually controlled LEDs
- Great DIY solder project



$39.95

$129

37 IN 1 SENSOR KIT XC-4288

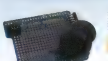
With 37 different sensors and modules, this kit covers just about every input and output you can poke a soldering iron at. Packaged in a clear plastic organiser.

SAVE UP TO 30% ON THESE DISCONTINUED ARDUINO® COMPATIBLE PRODUCTS

NOW $11.95
SAVE $4

OLED STICK MODULE XC-4245 WAS $15.95

NOW $29.95
SAVE $4



OLED SHIELD XC-4269 WAS $33.95

NOW $29.95
SAVE $15

8 CHANNEL RELAY DRIVER SHIELD XC-4276 WAS $44.95

NOW $34.95
SAVE $5

H-BRIDGE MOTOR DRIVER SHIELD XC-4264 WAS $39.95

ARDUINO® PROJECT OF THE MONTH

ARDUINO RFID KEYPAD

Here's a versatile security project inspired by our LA-5353 RFID Keypad and using the new XC-4630 LCD Touchscreen. If you want to be able to activate a relay with either a card (most smartcards like public transport cards and bank cards will work with it) or a PIN code, this project fits the bill. You'll find the setup of cards and users is relatively simple as with most Arduino security stuff, it's pretty easy to bypass if you have physical access to the main board, so we wouldn't recommend using it for protecting valuables. Some soldering required for this project (see page 4).

KIT VALUED AT $107.75

Finished project

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/rfid-keypad

NERD PERKS CLUB OFFER
BUY ALL FOR $79.95
SAVE 25%

WHAT YOU WILL NEED:

UNO MAIN BOARD	XC-4410	$29.95
240X320 LCD TOUCHSCREEN SHIELD	XC-4630	$29.95
RFID READER KIT	XC-4506	$19.95
PROTOTYPING SHIELD	XC-4482	$15.95
PLUG-SOCKET JUMPER LEADS	WC-6028	$5.95
RELAY MODULE	XC-4419	$5.45
10KOHM RESISTOR PACK	RR-0596	$0.55

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

IMPROVE THE PROJECT - ADD A DOOR STRIKE

NARROW ELECTRIC DOOR STRIKE LA-5077

You could use the Arduino® RFID Keypad to operate a door strike. Suitable for narrower doors. Fail-secure model. 12VDC 450mA.

$44.95

SWITCHMODE MAINS ADAPTOR 12VDC 1.5A MP-3486

Regulated output voltage, small size and higher power output make this AC adaptor suitable for thousands of different applications.

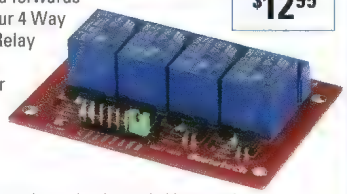
$24.95

RELAY MODULES XC-4418

Control a motor backwards and forwards without speed control, using our 4 Way (XC-4440) or 8 Way (XC-4418) Relay Modules. Plenty of power (up to 10A at 30VDC). 12VDC power supply required.

4 WAY XC-4440 **$12.95**
8 WAY XC-4418 **$19.95**

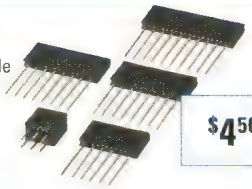
FROM $12.95



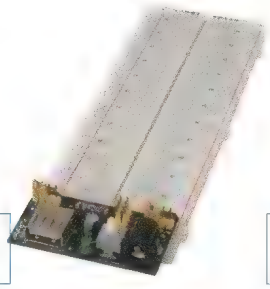
Not recommended for Stepper Motors, due to the slow switching speed.

ARDUINO® STACKABLE HEADER HM-3208

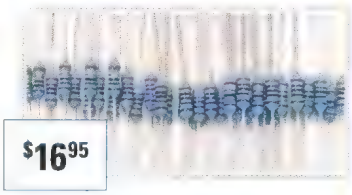
Build a stackable shield, or make your current shield stackable. Alternatively, shorten the pins to make female headers just like the Duinotech main boards.



$4.50



$19.95



$16.95

SOLDERLESS BREADBOARD WITH POWER SUPPLY PB-8819

830 tie-point breadboard with removable power supply module. Power from USB or 12V plugpack (not supplied). Includes 64 mixed jumper wires of different length and colour.

- 3V and 5V switchable output

RESISTOR PACK 300-PIECES RR-0680

This assorted pack contains 5 of virtually each value from 10Ω to 1MΩ.

- 0.5W 1% mini size metal film

See website for full contents.

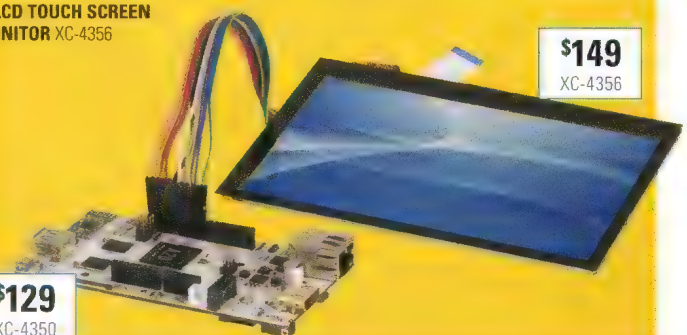
PCDUINO

If you want to take your Security or Home Automation project beyond what an Arduino® can process, then take a look at the PCDuino. A single board computer running a Linux operating system provides the processing power to run more complicated tasks. With built-in Wi-Fi, web interfaces and remote control are possible, and adding the 7" touchscreen will give your project a slick look.

NERD PERKS CLUB OFFER
BUY BOTH FOR $228
SAVE $50

PCDUINO V3.0 WITH WI-FI XC-4350

7" LCD TOUCH SCREEN MONITOR XC-4356



$149 XC-4356

$129 XC-4350

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. PLASTIC WELDING KIT
TS-1331 **WAS $99.95**
- Cordless gas-powered welder
- Fast heating process
- 4 plastic filler types included

2. NETWORK CABLE METER TESTER WITH DMM
XC-5078 **WAS $84.95**
- Measure AC/DC voltages up to 600V
- AC/DC current up to 200mA
- Resistance measurement

3. 6 PIECE INSULATED ELECTRONIC SCREWDRIVER SET TD-2026
- Ergonomic handles with non-slip grips.
- Fully insulated
- 1000V rated
- TÜV and GS approved

4. LCD TYPE ENGINEERS CALIPERS
TD-2082
- Surgical grade stainless steel
- 5 digit LCD display
- 0 - 150mm (0-6) range
- LR-44 battery powered (supplied)

5. 5 DIOPTRE LED ILLUMINATED MAGNIFYING LAMP
QM-3548 **WAS $119**
- Metal frame
- Manoeuvrable extension arm
- Mains powered
- 90 x bright white LEDs

6. 110 PIECE ROTARY TOOL KIT
TD-2451
- Drill, saw, sand, polish, carve or grind
- Ideal for hobby or professional use
- 12VDC at 12,000 RPM

$19.95

NOW $99 SAVE $20

$34.95

NOW $79.95 SAVE $20

NOW $79.95 SAVE $5

$39.95

60W ESD SAFE LEAD-FREE SOLDERING STATION

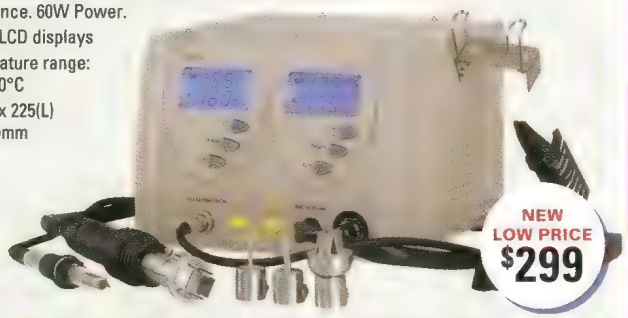
TS-1390

Particularly suited to lead-free soldering. High powered 60W heater. Easy temperature setting. Fahrenheit or Celsius temperature display.
- Backlit LCD display
- Temperature range: 160°C to 480°C
- 130(W) x 170(H) x 240(D)mm

NEW LOW PRICE $129

ESD SAFE SOLDER/DESOLDER REWORK STATION TS-1574

Complete solder/desolder station for production and service use. Microprocessor controlled for precise control of thermal performance. 60W Power.
- Backlit LCD displays
- Temperature range: 160 - 480°C
- 215(W) x 225(L) x 155(H)mm



NEW LOW PRICE $299

NERD PERKS CLUB MEMBERS RECEIVE:

50% OFF

SOLDERING TIPS* TO SUIT ABOVE SOLDERING STATIONS

Valid with purchase of TS-1390 or TS-1574. See T&C.

6" LONG NOSE PLIERS TH-1887

Precision, slim line long nose pliers ideal for working in confined areas. Serrated jaws for firm grip. Soft padded handles.
- 150mm long

$11.95 NERD PERKS 2x POINTS

STAINLESS STEEL SIDE CUTTERS TH-1890

High quality small side cutters with thick (2mm) blades. Spring loaded plastic handles.
- 115mm long

$13.95 NERD PERKS 2x POINTS

CRIMPING TOOL FOR NON-INSULATED LUGS TH-1834

Comfortable handles and spring-loaded. Handles non-insulated lugs from 14-18 AWG and 22-26 AWG. Includes a built-in wire cutter.
- 185mm long

$14.95 NERD PERKS 2x POINTS

WIRE STRIPPER TH-1824

Strips 0.2 to 6mm wire. One hand operation. Spring return.
- 170mm long

$16.95 NERD PERKS 2x POINTS

$19.95 NERD PERKS 2x POINTS

ROTARY COAX STRIPPER TH-1820

Handy stripper that will strip the outside jacket and inner conductor in one operation.
- Suitable for RG58/59/62/6 and 3C2V 75 ohm cable

NOW $19.95 SAVE $5 NERD PERKS 2x POINTS

ADJUSTABLE COMPRESSION CRIMPING TOOL TH-1800 WAS $24.95

A precision crimp tool ensuring correct crimping pressure is applied for reliable, trouble-free compression of BNC, RCA, Min-F and F-type coaxial connectors.
- Works with RG6 and RG59.

GUARANTEE CONTINUED OPERATION OF YOUR SURVEILLANCE SYSTEMS

MP-5224 NOW $129 SAVE $10

MP-5216 NOW $249 SAVE $50

MP-5205 NOW $129 SAVE $10

Protect your DVR from power failure with our value-for-money Uninterruptible Power Supplies. Initiates shutdown procedures in mains power blackouts. Ensures steady power supply during voltage drops/fluctuations.

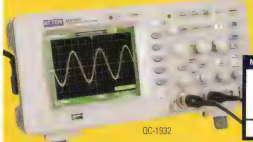
LINE INTERACTIVE UPS MP-5224	LINE INTERACTIVE UPS WITH USB MP-5216	LINE INTERACTIVE UPS WITH LCD MP-5205
WAS $139	**WAS $299**	**WAS $139**
Economical model	Desktop model	Desktop model
600VA, 300W	1500VA, 750W	650VA, 390W
12V/7AH x1	12V/9Ah x2	12V/7AH x1
Modified Sine Wave	Modified Sine Wave	Modified Sine Wave
Backup time: 31 mins / 11 mins / 4.5 mins	Backup time: 94 mins / 49 min / 31 mins	Backup time: 25 mins / 9 mins / 5 mins

HUGE SAVINGS!
NERD PERKS SPECIAL
DUAL CHANNEL DIGITAL OSCILLOSCOPES

The advantages of a DSO gives you capabilities that simply aren't possible with any analogue oscilloscope, including trace capture, PC interface, storage of data on portable media etc.

- Sampling rate: 500M Sa/Sec (QC-1932) / 1G Sa/Sec (per channel) (QC-1934)
- Memory depth: 32k (QC-1932) / 2mpts (QC-1934)

25MHZ DUAL CHANNEL WITH 5.7" SCREEN QC-1932 **RRP $689**
100MHZ DUAL CHANNEL WITH 7" SCREEN QC-1934 **RRP $1129**



QC-1932

NERD PERKS CLUB OFFER
SPECIAL $449
SAVE $240

QC-1934

NERD PERKS CLUB OFFER
SPECIAL $749
SAVE $380

CAT III CLAMP METERS

Our range of CAT III Clamp Meters makes the best general troubleshooting tool for commercial and residential electricians and includes features found on more expensive units such as autoranging, data hold, non-contact voltage, relative measurement and auto power-off. Multi function with Resistance, Capacitance, Frequency and Temperature, all Clamp Meters are supplied with quality temperature probe and carry case.

NERD PERKS RRP $69.95 $64.95 SAVE $5

400A AC QM-1561
- Cat III 600V, 4000 count
- AC/DC voltage < 600V
- AC current < 400A
- Jaw opening 30mm

NERD PERKS RRP $129 $119 SAVE $10

400A AC/DC QM-1563
- Cat III 600V, 4000 count
- AC/DC voltage < 600V
- AC/DC current < 400A
- Jaw opening 30mm

NERD PERKS RRP $159 $149 SAVE $10

1000A TRUE RMS AC/DC QM-1566
- Cat III 600V, 6000 count
- AC/DC voltage < 600V
- AC/DC current < 1000A
- True RMS, min-max, bargraph and more
- Jaw opening 40mm

TOOL MAGNETISER & DEMAGNETISER TD-2042

This tool has two slots, one which will magnetise and the other to demagnetise. The holes are large enough for the largest of screwdrivers.

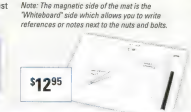
- 50 x 50 x 30mm

$6.95

8X10" MAGNETIC MAT TH-1867

This mat is great for keeping nuts and bolts in place when disassembling all kinds of gadgets and phones.

Note: The magnetic side of the mat is the "Whiteboard" side which allows you to write references or notes next to the nuts and bolts.

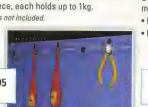


$12.95

HANDY MAGNET STRIP LM-1624

Simply attached to walls, tables or other surfaces to hold tools, brushes, scissors, keyrings, or any other object that contains iron. 9 piece, each holds up to 1kg.

Note: Tools not included.

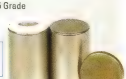


$19.95

LARGE RARE EARTH MAGNETS - PAIR LM-1652

Made from NdFeB (Neodymium Iron Boron), providing the highest available magnetic energy of any material.

- Nickel coating
- NdFeB, N35 Grade



$29.95 pr

CAMERAS FOR REMOTE MONITORING ANYWHERE, ANYTIME, DAY OR NIGHT

NOW $59.95 SAVE $10

QC-3694

NOW $79.95 SAVE $10

QC-8654

NOW $99 SAVE $30

QC-8637

NOW $129 SAVE $20

QC-8668

NOW $199 SAVE $20

QC-8670

Keep watch over the things that matter to you most from anywhere at any time, offering you peace of mind at the tip of your fingers. Customise your surveillance system with our range of high quality 12VDC standalone cameras with supreme resolution ranging from 420TV lines to 720p. Easy installation, unbeatable value!

	QC-3694	QC-8654	QC-8637	QC-8668	QC-8670
	WAS $69.95	WAS $89.95	WAS $129	WAS $149	WAS $219
Resolution	420TVL	700TVL	720p AHD	720p AHD	720p AHD
Illumination	Infrared	Infrared	Infrared	Infrared	Infrared
Camera Type	Mini	Dome	Bullet	Bullet	Bullet
Sensor	1/3" CCD	1/3" CMOS	1/4" CMOS	1/3" CMOS	1/3" CMOS
Lens	3.6mm	3.6mm	3.6mm	2.8 - 12mm (Vari-Focal)	3.6mm (Pan-Tilt)

$1.60/m

CCTV COMBO CABLE

WB-2017 **$1.60/m or $139/100m roll**

Combines RG59 coax and 16G power cable. Also sold in 100m roll.

FROM $6.95

ILLUMINATED POLARITY SENSING DC CONNECTORS

Simplifies installation of your CCTV cameras, access control and other security applications.

INLINE PLUG WQ-7286 **$6.95**

INLINE SOCKET WQ-7289 **$7.95**

$14.95

BNC TO CAT5E/6 UTP AHD VIDEO BALUN KIT QC-3667

Extend the transmission distance of your CCTV setup.

$19.95

ECONOMY CCTV VIDEO / POWER CABLES WQ-7279

Make running cables between your cameras and your DVR a breeze using these integrated video and power cables. BNC terminated and DC power connectors. 18m long.

$19.95

CCD CAMERA POWER SUPPLY MP-3011

500mA regulated switchmode plugpack. Terminates to a 2.1mm DC plug, centre positive, 12VDC.

FROM $19.95

CCD CAMERA EXTENSION LEADS WQ-7275

Easy way to extend the length of CCD camera cables. They have 3 joined cables, BNC plug to plug, RCA plug to plug and DC power male to female.

5M LENGTH WQ-7275 **$19.95**

10M LENGTH WQ-7276 **$34.95**

15M LENGTH WQ-7277 **$44.95**

20M LENGTH WQ-7278 **$59.95**

FROM $2.95

SURVEILLANCE WARNING STICKERS

- UV stabilised for long life
- Black printing on a clear background

SMALL (INSIDE WINDOW) LA-5106 **$2.95**

SMALL (OUTSIDE WINDOW) LA-5107 **$2.95**

LARGE (OUTSIDE WINDOW) LA-5108 **$3.95**

$14.95

SURVEILLANCE WARNING SIGN LA-5115

Visual deterrents to warn thieves off.

- Made of acrylic
- Lightweight and durable
- 300(W) x 300(H)mm

CCTV WARNING SIGN LA-5114

Prominent warning sign for CCTV or dummy surveillance applications.

- Made of acrylic
- 300(W) x 210(H)mm

$14.95

ACCESS CONTROL

NON-CONTACT INFRARED DOOR EXIT SWITCH LA-5187

Trigger an electronic latch with just a wave of a hand. No physical touch required.

- 3A @ 30VDC contact rating
- 12VDC
- 70(W) x 115(H)mm

$69.95

DIGITAL KEYPAD WITH RFID ACCESS CONTROL LA-5353

Suitable to areas requiring stricter access control such as a laboratory, warehouse, bank, or prison.

- Support up to 2,000 users
- Backlit keypad
- LED indicator (Green/Yellow/Red)
- Built-in buzzer
- 128(H) x 82(W) x 28(D)mm

$129

NERD PERKS CLUB MEMBERS RECEIVE:

25% OFF

ALL WARNING SIGNS & STICKERS*

*Applies to LA-5101, LA-5102, LA-5106, LA-5107, LA-5108, LA-5114 & LA-5115.

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

SECURE YOUR PROPERTY

NOW $139 SAVE $20

NOW $109 SAVE $20

NOW $259 SAVE $40

4 ZONE KIT WITH 2 WIRE TECHNOLOGY
LA-5475 **WAS $159**

Utilises two-wire technology to ensure simple set-up.
- Wired Connection
- 4 Zones
- Multiple Operation Modes
- 180(H) x 113(W) x 47(D)mm

INCLUDES:
1 x Control unit
2 x Movement detector PIRs
4 x Door/window contact
1 x External siren
1 x 240VAC adaptor
1 x 50m two-core flat wire and clips
Mounting hardware

8 ZONE WIRELESS KIT WITH REMOTE CONTROL LA-5280 **WAS $129**

Quick and easy installation, eliminating the mess and expense of running cables.
- Wireless Connection
- 8 Zones
- Multiple Operation Modes
- 150(H) x 100(W) x 30(D)mm

INCLUDES:
1 x Smart panel with tri-colour LCD display
1 x Motion sensor with mounting bracket
1 x Door/window sensor
1 x Keyfob remote control with battery
1 x Mains power adaptor
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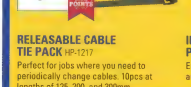

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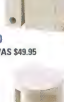

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

Want a 200kHz LCD Scope for about $40.00? One tiny catch: First you have to build it!

You get the complete kit, as shown here, with the instruction manual. Inset below is the clear acrylic case, ready for assembly.

Jim Rowe looks at the

"Banggood" DSO138 LCD Scope Kit

We've looked at some very cheap modules from China in recent months. Here's one that more-or-less fits into the same category – except that for the princely sum of $40 (or less!), you get a real, working Digital Sampling Oscilloscope kit. It's from Banggood and you really do get a good bang for your buck!

Sixty or so years ago, the only way that most people could acquire even a basic oscilloscope was to build it yourself, using components salvaged from war-surplus equipment. Even then, by-and-large, most were only "audio" scopes with, perhaps, 10kHz bandwidth.

Commercial scopes were so expensive that they could only be afforded by large manufacturers and research labs.

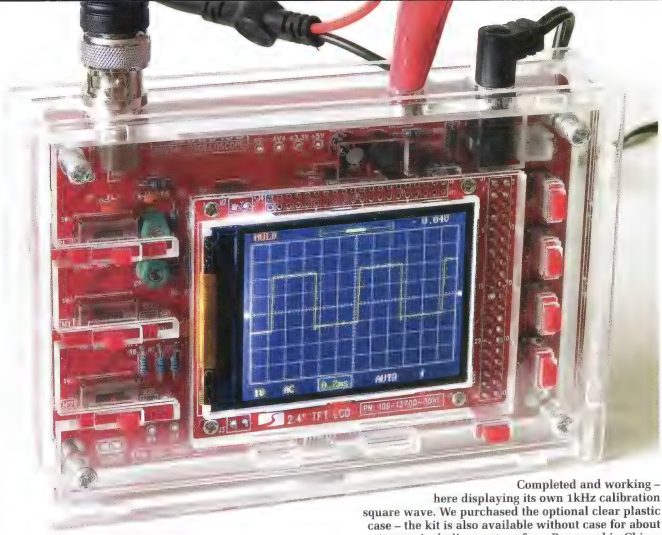
That was back in the valve era and things soon began to change for the better when the solid-state revolution got under way. Before long the cost of commercial scopes started to fall, while at the same time their performance climbed steadily, especially in terms of analog bandwidth.

But the real breakthrough came with digital sampling scopes and particularly when cheap LCDs (liquid-crystal displays) started to replace the costly CRTs (cathode-ray tubes) which formed the heart of all the early scopes. This eliminated the need for an expensive high voltage power supply and also enabled many useful features to be added while the cost of scopes continued to plummet.

So nowadays you can buy a wide selection of digital sampling oscilloscopes or "DSOs" at quite reasonable prices. Handheld, single channel, battery-operated units with 10MHz analog bandwidth are available for less than $370, while 4-channel 100MHz bandwidth benchtop models cost less than $800. You can even get a 2-channel 300MHz MSO (mixed signal oscilloscope) for around $3000.

What if you only need a scope occasionally, and don't need a lot of bandwidth – for example, if you're mainly working on audio equipment? This would make it hard to justify an outlay of even $370. But this kit is around 1/10th of that amount!

It's known as the DSO138 and recently has become very popular all around the world. It's available from online retailer Banggood, which has its main office and warehouse



Completed and working – here displaying its own 1kHz calibration square wave. We purchased the optional clear plastic case – the kit is also available without case for about $30.00, including postage from Banggood in China.

in Guangzhou, China. The firm has over 1000 employees with offices in nearby Shenzhen and Hong Kong as well as Hangzhou and Yiwu, plus offices in the UK and USA.

The electronics part of the kit is manufactured by the firm JYE Tech Ltd, based in Guangxi, China. The manufacturer of the laser-cut acrylic sheet parts which are used to make up its custom acrylic case (as shown in the photo of the completed unit above) is not specified but is presumably also in China.

If you look at the Banggood website (www.banggood.com), you'll find that the DSO138 kit is available in two forms: one with all of the SMD components already soldered in place on the main PCB, leaving only the through-hole components for you to fit and solder, and one with just the SMD CPU pre-soldered.

We're reviewing the version with all SMDs pre-soldered. It's known as the 13803K (product ID 1051616), and is currently available for only AU$33.17, with acrylic case and with free "standard shipping" to Australia.

The other version is known as the 13804K, and is currently available from Banggood for AU$41.30, also with case and free delivery to Australia (product ID 1051617).

So it not only costs more, but you have more work to do building it up. You can see why we chose the 13803K version to review!

By the way, both versions are also available without the matching assemble-it-yourself acrylic case. But if you want to buy it later, or you need to replace it, it's available separately from Banggood for only AU$8.60 (at press time) including delivery (product ID 1034768).

The electronics

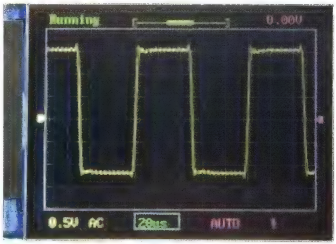
Apart from the DSO138's 2.4-inch colour TFT LCD screen (320 x 240 pixel resolution), which is mounted on a small PCB of its own, all the rest of the kit's electronics mount on a single PCB measuring 117 x 76mm. And as noted above, the PCB in the 13803K kit has all of the SMD parts already fitted: nineteen 0805 resistors, two ICs and an LM1117-3.3 LDO regulator in a TO-263 package. Everything else in the kit is in the form of through-hole components and connectors etc for you to fit yourself.

The two ICs are a TL084 quad op amp, used for processing the analog input signal and generating trigger pulses, and the STM32F103C8 CPU which does everything else.

The STM32F103Cx is in a QFP-48 package and is a 72MHz, 32-bit ARM Cortex-M3 processor, with the following features: 64KB of flash memory, 20KB of SRAM, two 12-bit/1MHz ADCs providing up to 16 analog input channels, seven different timers, a full-speed USB 2.0 interface, two I^2C interfaces, two SPI interfaces (18Mb/s), three USART interfaces and a 7-channel DMA controller.

So it's quite capable of doing all of the sampling, display and other work needed to perform the functions of a basic audio DSO – with the right firmware, of course.

A close-up of the LCD screen before mounting in the case, showing a 10kHz square wave. No-one is pretending that it's perfect – obviously not as good as you'd find on a multi-hundred (or multi-thousand!) dollar DSO . . . but for around $40.00, the DSO138's performance is surprisingly good!



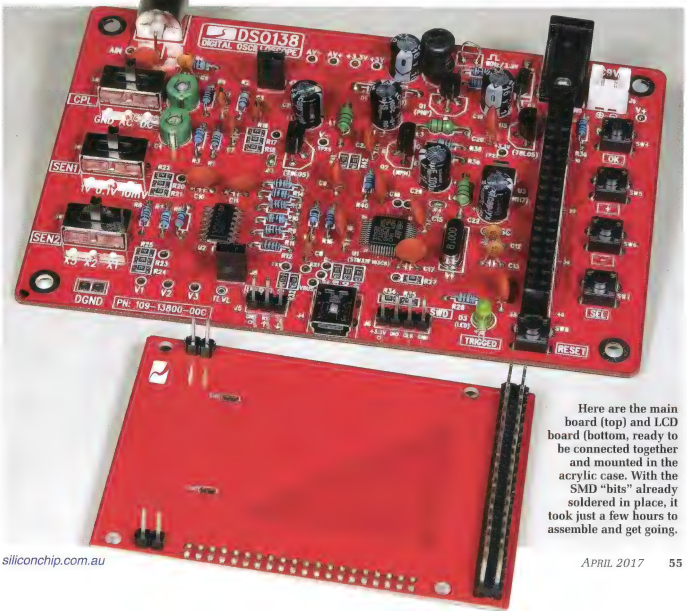
Assembling the PCB is fairly straightforward because JYE Tech has provided the kit with a double-sided A4 instruction sheet with 22 numbered assembly step boxes – each one accompanied by a small but clear colour illustration. Each step also has a checklist, allowing you to tick each component's box as you fit it.

The instruction sheet has quite a few helpful hints, like advising you to check the value of each resistor with your DMM before soldering it into the PCB. This is good advice, because the coloured bands on the tiny 1/8W resistors are hard to see even with a magnifying glass.

There's also a guide to checking the voltages on the DSO138's main PCB following assembly, attaching the LCD board and then giving it a basic functional checkout. And there's a troubleshooting flowchart, an explanation of the self-test mode built into the firmware and a picture of the main PCB showing the location of all important test points.

By the way, a PDF file of the instructions can be downloaded from the JYE Tech website (www.jyetech.com), so you can preview it before buying the kit and you can also download another copy if you lose or damage the original.

There's a second instruction sheet in the kit, intended to familiarise you with the DSO's various controls and their use. In addition, there's a section on using the built-in 1kHz squarewave signal to adjust the frequency compensation



Here are the main board (top) and LCD board (bottom, ready to be connected together and mounted in the acrylic case. With the SMD "bits" already soldered in place, it took just a few hours to assemble and get going.

of its input divider and any divider probe you connect to its input. There's also a specification panel, plus a full schematic of the scope on the back of this second sheet.

In short, the PCB has been carefully designed to be easy to build and get going.

The JYE Tech website also has a four-page booklet you can download, explaining how to upgrade the firmware in its CPU, an 8-page booklet explaining how to use the library of functions built into its firmware and a single sheet showing an overlay diagram of the main PCB.

Assembling the box

Since the PCB assembly is so straightforward, you might expect the case would also come with clear instructions and that it would be easy to put together. But it isn't quite that easy.

All you actually get are the nine laser-cut pieces of acrylic sheet plus a small plastic bag with some control switch extension pieces moulded in red plastic, and some M2.5 and M3 machine screws and nuts.

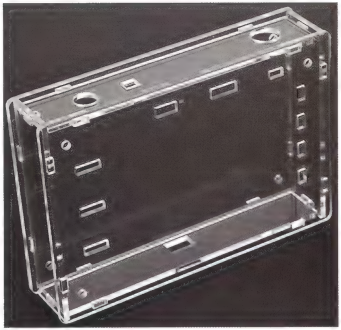
The acrylic pieces are covered in protective paper sheet on both sides but there is no information on how to put it together.

Perhaps this is supposed to be self-evident but after a while I gave up and went to the Banggood website to look for clues. I subsequently found several links to YouTube clips showing the assembly of the DSO138 case. (See www.youtube.com/watch?v=9vtHZP2_KAU).

By playing the clip quite a few times – and pausing here and there as well – I was finally able to get the sequence right. (There are several other clips – simply go to YouTube and search for "DSO138 case").

There was one further little complication with regard to the red plastic control switch extension pieces. These allow you to operate the small slider switches and pushbuttons on the PCB when it's mounted in the case.

The extension pieces for the three slider switches were easy to identify, because they are T-shaped with a small locating slot moulded into the top centre of the "T" (which actually becomes the bottom of the extension). But the extension pieces for the five pushbuttons were harder to work out.



Taken from Banggood's website, this shows the assembled case without any content, to show you how all the outer pieces of the box fit together.

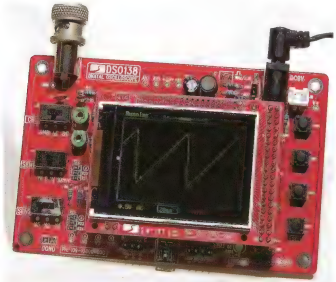
They seemed to be I-shaped with a bump at both ends, and there seemed to be only three of them in the kit instead of the five I was expecting.

Had someone made a mistake? No, because I eventually realised that each "I" piece was actually two small "T" pieces moulded together with a fine central groove which allowed them to be snapped apart. After this I didn't have any problems, and it all went together nicely as shown in the photo.

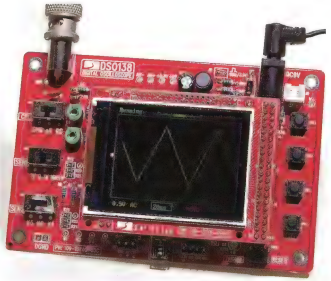
Performance

Putting the completed DSO138 through its paces was a pleasant surprise. The analog bandwidth measured -1dB at 150kHz, -2dB at 175kHz and -3dB at very close to the 200kHz stated in the specification.

So a 10kHz square wave signal displays quite nicely,



Here the DSO138 is displaying a 10kHz sawtooth wave . . .



. . . while here it's a 10kHz triangle wave.

confirming that the DSO138 is practical as a basic scope for audio testing.

The maximum real-time sampling rate is 1MS/s, with a vertical resolution of 12 bits and a record length of 1024 points. The input sensitivity range spans from 5V/division down to 10mV/division, while the input impedance is 1MΩ shunted by approximately 20pF – pretty much standard.

The rated maximum input voltage is 50V peak (100V peak-to-peak), so for measurements in higher-voltage circuits you'd need to use it with a 10:1 divider probe.

The timebase range is from 10µs/division down to 500s/division – more than adequate for an audio scope. There are three selectable triggering modes: Auto, Normal and Single(shot) and the trigger level is fixed at 50% but this should again be acceptable for primarily audio use.

Incidentally, I don't know if you'll be able to see this in the photos, but although the active part of the DSO138's 2.4-inch TFT LCD screen is fairly small (49 x 37mm), its resolution of 320 x 240 pixels with 262,144 colours results in a very sharp and well-defined display.

I should also mention that the DSO138 is designed to run from a nominal 9V DC supply but since its current drain is around 120mA, it isn't feasible to use a standard 216-type 9V alkaline battery. The simplest options are a 9V DC regulated plugpack or a pack of six AA or C size alkaline cells in series.

However, JYE Tech also have a very small step-up DC-DC converter module, the JYE140, which can be used to provide the DSO138 with 9V DC derived from a standard low-cost 5V DC plugpack or Li-Ion battery. Based on an MC34063 converter chip, the JYE140 has an output current capability of 150mA, an output ripple of around 100mV at full loading and its output can be plugged directly into the rear of the DSO138.

If you are interested in this option, the JYE140 converter can also be ordered online from the Banggood website for AU$5.15 (product ID 1000089), again with free delivery to Australia. At that price, you certainly wouldn't bother to build it yourself!

The final verdict

Overall, I'm happy to give the JYE Tech/Banggood DSO138 scope kit a rating of 4.5 stars out of five. The electronics side of the kit is easy to put together and seems well-designed.

Features like the inbuilt 1kHz square wave probe calibration signal output and the self-test function testify to this, and makes the kit well above average given its low price.

The DIY acrylic box is quite good too, once you have figured out how to put it together. And the performance of the completed DSO138 is quite good enough to qualify it as a useful tool for audio testing and troubleshooting.

The DSO138 kit represents outstanding value for money. It's almost worth buying just for the fun of putting it all together and trying it out, even if you're going to give it away!

Where from?

As mentioned earlier in the article, our DSO138 Scope came direct from the Banggood online store (www.banggood.com). The prices quoted were what we paid; however with the Aussie dollar fluctuating as it does, the price you pay could be slightly higher or lower. SC

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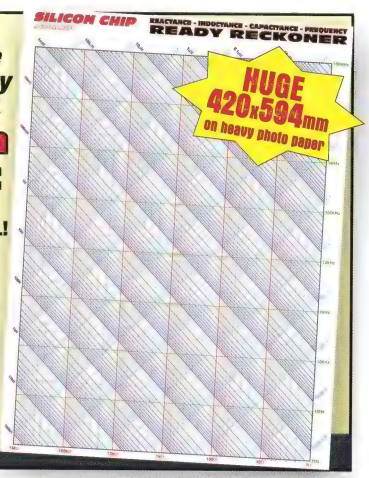

SERVICEMAN'S LOG

Dave Thompson*

Stomping on the pedal killed it

We all know that musos need to stomp on their effects pedals as they weave their magic. But ultimately that stomping can kill the pedal and the good thing is that it then needs a repair. Hopefully, they then know "who they're gonna call"!

Items Covered This Month

- Wah-wah pedal repair
- Dishwasher cockroach removal
- Gas igniter repair
- Technics SZ-4000U amplifier

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The term serviceman means different things to different people. 60 years ago, a serviceman was typically someone in uniform, most likely heading off to, or returning from, a war.

These days, a serviceman can be the person who turns up to fix your washing machine or TV, or the person who checks the oil and air filters on your car. Those who call themselves servicemen (or women) cover a huge range of careers and callings and that is what makes being a serviceman so interesting; we cannot usually be easily pigeon-holed into any one job or service.

My current job title would be computer serviceman but that description doesn't cover my skill-set and other servicemen probably feel the same way. Most of us bring a range of skills to our trade and this is what sets the serviceman apart from some other tradespeople.

There are plenty of servicemen out there who have no experience in fields other than the one they specialise in, and while there's absolutely nothing wrong with that, those who do bring outside skills to their trade will raise the bar for others and that can only be a good thing.

Having skills in the model aircraft-building and hobby electronics fields, for example, can be a real boon for my computer repair work, as every now and then I'm faced with a task that requires soldering, custom fabrication or other outside-the-box aptitudes that others in this trade might have to outsource in order to provide the service.

I'd like to think this gives me an edge in business, though given there are plenty of very skilled technicians out there, that might be just wishful thinking!

I mention this because I had a job recently that required a range of skills to resolve. Since I've been diversifying into musical instrument and amplifier repairs in order to keep my accountant happy, I've had some interesting jobs through the workshop. However, this field also has some challenges to the serviceman and having been a working musician certainly helps me with insights into that world.

One rather large flaw in choosing this line to diversify into is that 99% of working musicians operate on very tight budgets, from which they have to set themselves up in what can be a shockingly expensive business. This means there is a lot of compromise and innovation as musos try to get by with whatever gear they can afford. It doesn't help that guitarists in particular are usually searching for an elusive 'sound' to call their own.

And those 'sounds' are big business; all the top guitar players have their signature tone and playing style that others try to emulate, so much so that manufacturers of so-called 'modelling amplifiers' try to 'bottle' those sounds so other players can easily replicate them (if they buy that amplifier of course!). That's a pretty big ask, given that those sounds are much more than just what comes out of the speakers.

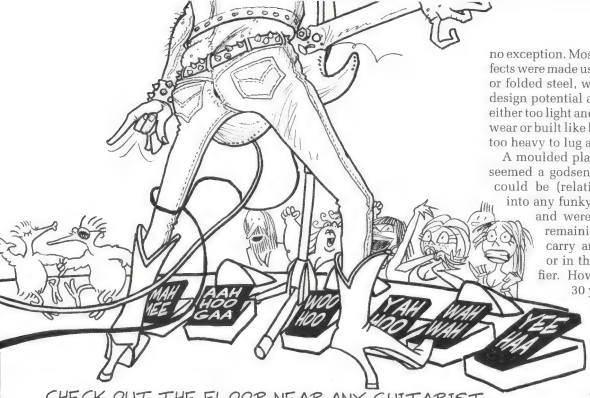
A player's tone is a combination of many different factors, from the mass of the player's hands and fingers to the way they strum, pick, hammer-on and tap the strings through to the construction of the hardware itself, such as the timber the guitar is made from, whether it is solid or hollow, the size and type of strings, the way the instrument is tuned, the pick-ups and on-board controls and type of amplifier and speakers, the sum of which have a profound effect on the overall sound.

All this variation means a lot of work for the instrument and amplifier serviceman, who sometimes must tread very carefully when repairing or servicing some of this gear. It also means that costs have to be sensible and keeping costs down means not spending too many non-chargeable hours working away on problematic gear, which comes back to having the skills to do these jobs quickly and efficiently. It is sometimes a fine line to walk.

While this job turned out to be more mechanical than electronic, it did have a troubleshooting sting in the tail. The customer brought in what is generically known as an effects pedal, which is typically a foot-operated device that sits on-stage and is positioned in-line between the guitar and the amplifier. These boxes modify the guitar's signal in some way before piping it onwards.

Check out the floor near any guitarist playing live and you'll often see a gaggle of these pedals within easy reach. Some guitar players don't use any floor effects, while others might have a large pedal-board chock full of them; it is very much a personal preference.

This job involved a 'Wah-Wah' pedal, one of the earliest and most audibly recognisable of all the guitar effects. The wah-wah pedal as we know it today hails from the mid to late 1960s and was introduced to the masses by



CHECK OUT THE FLOOR NEAR ANY GUITARIST PLAYING LIVE & YOU'LL OFTEN SEE A GAGGLE OF THESE PEDALS WITHIN EASY REACH.

musical experimenters such as Jimmy Hendrix and Frank Zappa, though it has been used in every genre of music from jazz, country, funk and disco to the heaviest high-gain rock.

Essentially just a variable notch filter, the effect is controlled by the up and down movement of a foot operated pedal, giving the guitar a 'crying' sound. While sometimes regarded as a bit of a 'joke' effect because the wide range of sounds produced makes it prone to over-use by inexperienced players, it was hugely popular throughout the 1970s before falling out of fashion in the 1980s.

Lately, the wah-wah pedal has seen a resurgence due to its adoption by hipster bands and lovers of retro, 'analog' effects. This means that some of the original pedals, which you once couldn't give away, are now worth a small fortune.

Most of them boasted remarkably simple, PNP transistor-based circuits, which modern manufacturers attempt to emulate with all manner of digital jiggery-pokery whilst creating newer, quieter versions for today's noise-allergic players. However, many roll-your-own effects pedal makers – and there are a huge number of us out there – prefer those early designs, making vintage germanium PNP transistors like AC128s and OC71s and diodes like 1N34s suddenly quite desirable (and therefore valuable). Luckily, I have parts-drawers full of them; Easy Street, here I come!

The pedal I had to repair is an Ibanez WF-10 Wah-Fuzz, a late-1980s-era pedal made in Japan and now quite sought-after. It has a unique sound and this is why the owner wanted it repaired.

The effect, as the name suggests, consists of a wah pedal with a fuzz circuit built-in. Switches beneath the foot-pedal activate the bypass system to switch the wah effect in and out and a fuzz on/off switch and depth control lurk on the bottom left side of the case.

This WF-10 had lost its wah due to a broken linkage mechanism, leaving the pedal part of it disconnected and flopping uselessly up and down. The linkage is a clever plastic and metal arrangement that converts the up-and-down action of the foot-pedal into the rotational movement required to turn a potentiometer throughout its range. I'd need to re-create that linkage to restore wah functionality.

One of the problems facing many older pedals, and this family of Ibanez pedals in particular, is with the injection moulded plastic case. It obviously seemed like a good idea back in the day, but time is the nemesis of most plastics and the WF-10's case is no exception. Most early foot pedal effects were made using pressed-tin and/or folded steel, which meant limited design potential and the pedals were either too light and flimsy to take stage wear or built like brick outhouses and too heavy to lug around.

A moulded plastic case must have seemed a godsend at the time; they could be (relatively) easily made into any funky, fashionable shape and were very strong while remaining light enough to carry around in a gig bag or in the back of an amplifier. However, fast-forward 30 years and one of the consequences of using plastics has become all too clear.

The owner of this pedal reported that he stomped on it one day and with a sickening crunch, the thing fell to bits beneath his foot, leaving fragments of plastic and distorted metal scattered everywhere. He scooped the whole lot up into a bag and brought it to me to see if I could do anything with it. I understood why he wanted to save it; it was part of his 'sound' and finding a substitute would be difficult, unless he could locate another WF-10 that is . . .

It was easy enough to see what the problem was; the plastic mounting lugs at the foot-pedal end of the linkage had shattered due to age, leaving nothing for the metal to hold onto. These bits and the linkage then fell through the gap in the bottom part of the pedal and had been crushed by the pedal coming down on top of it, causing the metal to bend and inflicting more damage to the plastic bits directly beneath it, including the pot mounts, which were cracked and would also need repairing.

Fortunately, the rest of the case was OK. It didn't really have that much stress put on it during normal use and so would likely last a few more years yet. Any repair would entail rebuilding those mounting points and making them stronger than they were before, allowing for the fact the plastics were still going to be deteriorating and there wasn't much I could do about that.

Ideally, I'd like to swap out the whole chassis with a new one but that wasn't an option. A quick look on eBay showed a number of these

Serviceman's Log – *continued*

pedals for sale, but all were as old and would probably have the same issues as this one; besides that, the cost was prohibitive, so I decided that reconstructing the mounting lugs was the best way to proceed.

The first thing was to split the two halves of the pedal before stripping the jack sockets, circuit board, pots and switches from the case and giving everything a good clean.

Since the top of the bottom half of the case has a slot to allow the linkage through, it is open to the elements and as it sits on the floor on-stage, it tends to accumulate everything from generic dust and dirt to ash, sweat, spilt booze and other nasty stuff; Rock and roll is so glamorous!

Thankfully my customer had the good sense to grab all the broken plastic bits he could find and it seems he got them all. It was simple enough to fit them all back together like a 3D jigsaw but some of the bits had been distorted and didn't fit as well as they could, so there was a fair bit of carving and fettling and assembly to be done until everything fitted together as well as it was going to.

I used an expensive, good-quality 24-hour epoxy to glue these bits, mainly because cheaper epoxies, and especially the 4 and 5-minute versions, are a lot weaker than their longer-curing cousins. I wrapped the drying brackets in grease-proof paper and clamped them using small, spring-loaded clamps similar to clothes-pegs on steroids, to ensure everything was straight. I left it all for longer than 24 hours, checking periodically early on to make sure it was still lined up.

In the meantime, I used my metal-working skills to straighten out the bent linkages and brackets. Once the glue was set, I tried test-fitting everything to make sure it all fitted; after a bit of glue-clearing with a hobby-knife and a drill bit, it did. However, while that repair might last, leaving it like this would invite failure somewhere down the line, so I needed to strengthen it further.

This I did by using what I politically-incorrectly call "poor man's fibreglass". Years ago, when I was building my Lotus 7 replica, I did a lot of fibre-glassing. I used several weights of spun-glass cloth for the nose-cone and guards and some scraps of the lightest mat would be ideal for this pedal repair. I cut several small strips to size and mixed up a small amount of the same 24-hour epoxy, which I 'painted' onto the lug before wrapping one of the strips of cloth over it. I then painted more glue onto the cloth, working it well in until it was saturated.

I applied the other strip the same way and after cleaning any potential run-off, I again wrapped the whole thing in grease-proof paper and held it in place with strips of rubber band material.

When the glue was dry, the rubber and paper came away easily, leaving a nice, smooth finish. While the repaired mounting lugs were a bit bulkier than they were originally, we had room and they would now be many times stronger and less likely to fail again.

Reassembling the pedal was straightforward and all that was required was a sound check. I put a fresh 9V battery into the pedal's battery bay and plugged my trusty Telecaster into the input jack, with the output going to my 5W bench amplifier. I stepped on the pedal to light it up, wound up the volumes and strummed a few chords; nothing.

While there was some sound, it was way in the background, even with volumes cranked up. I checked switches and wiggled cables but there was no change. This was not really what I was expecting, but no problem; I'm a serviceman!

Fortunately, the WF-10 was popular enough for there to be several scans of user and service manuals online. In fact, there are circuits for effects of all types and ages because fans and experimenters reverse-engineer them in order to find out what makes them tick and at the same time draw up schematics and post them online. Very handy!

The WF-10 is very much an 1980s-era effects box, utilising through-hole components and commonly-available parts. Having a schematic makes things easier but the more I thought about it, the more I was convinced this was related to the broken linkage.

A quick look over the board and sockets didn't reveal anything obvious but I recalled the guy's description of how it broke; he said the linkage gave way as he stepped on the pedal, so I took a much closer look at the area of the board surrounding the gap in the bottom case where the linkage goes through with my jewellers' loupe and there it was, one of two diodes sitting parallel to each other near the edge of the board beside the linkage had a faint crack in the glass body.

My Peak semiconductor checker told me it was open circuit, so I removed it. I used the tester on the other diode and it told me it was a standard component, so I soldered in a 1N4148, plugged everything in on the bench and tried again. This time I had full sound and after reassembling the pedal, I invoked the spirit of Jimi Hendrix and gave the pedal a thorough test. Job done.

Editor's note: Silicon Chip has published a number of effects pedals over the years and these can all be accessed by searching under the "Articles" tab of the home page of the website. Specifically, we published a wah-wah pedal (we called it "waa waa") in September 1998. All the parts are still available although the PCB is not. Go to http://siliconchip.com.au/l/aacc

More recently, a Digital Effects Processor for Guitars & Musical Instruments was publish in October 2014. All key parts, including the PCB, are available. Go to http://siliconchip.com.au/l/aacd

Dishwasher stopped by roaches

B. C., of Dungog, NSW, has had a battle with a dishwasher and its eccentric owner. He managed to repair the machine in spite of the owner's odd ways. Call it a "pro bono" job.

Freda (not her real name) lives close to the beach and her house has been the preferred location for family get-togethers. During a recent visit, Freda's dishwasher (Dishlex DX302WJ) had developed a weird problem. Unfortunately, this appliance has not had an easy life and has had (what I would call) various environmental faults over the years. In more recent times, it has been rarely used, to save on water and electricity.

As I was already there on the spot, my services were enlisted. Freda said the machine had been working perfectly but admitted that she had forgotten to turn on the stop cock (mounted under the sink). Then the dishwasher would not run through the Quick cycle. She had then turned the water back on but it would now only show E10 on the display and would not fill up with water.

Freda said to me, "I am sure that all you have to do is find the blockage in the inlet hose and it will be working again". I foolishly asked "why don't you just leave the stop cock turned on". Her reply was, "I always turn it off, in case a rat chews through the water hose. That way my kitchen does not get flooded".

Under these strict instructions (to only check the water hose), I rolled up my sleeves and faced up to the challenge.

Checking first that both the power and the water were turned off, I put a hessian bag on the floor and slid the dishwashing machine out. I found a position where I could inspect it underneath and still have access to do the necessary testing and repairs.

I could see the wiring harness around the wash motor had been repaired and the water inlet hose appeared to have been re-joined near the back of the machine. Perhaps in the past, a rat *did* chew through the water inlet hose, resulting in the flooding of the kitchen!

I then removed both the rubber hoses that were connected to the water inlet solenoid valve. I first removed the water filter gauze from the end of the inlet hose and found it to be clear of debris.

Then the free end of the water inlet hose was put into a plastic bucket. The stop cock was turned on briefly and plenty of water gushed out. Blowing through the water outlet hose (from the solenoid valve) proved there was no blockage.

So it was now time to test the solenoid coil. The original two harness wires were disconnected, ready for this test to be done. Set on a low Ohms range, the multimeter showed that there was continuity in the coil and I then proceeded to test the solenoid valve on mains power.

A suitable test lead was made up from a discarded figure-8 power lead, with a lamp holder wired in series and then fitted with some fast-on connectors.

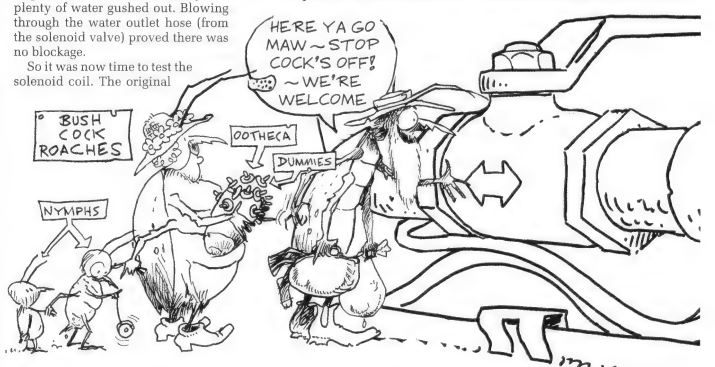
A 100W globe was put into the lamp holder and this test lead was connected to the coil terminals. When the mains power (current limited by the light globe) was applied, the globe lit up but the solenoid valve made no noise at all; it appeared to be stuck in the closed position and needed to be replaced. I managed to salvage one from another dishwasher, sitting in the backyard appliance graveyard.

I tested it first with my mains power test lead. It made a noise as it operated and the globe went back to a dim glow. This solenoid valve was then installed into the machine and the water hoses and cables were reconnected. I put the machine onto the quick cycle and I could hear the water flowing into it. But I could also hear the drain pump motor running as well. As fast as the water was flowing in, it was getting pumped back out again!

Over a period of time, dishwashers can have debris accumulate down inside the sump housing, particularly when some owners do not bother to regularly clean and refit the filters correctly. To get access to the lower section of the sump housing, it would be necessary to take it completely out of the machine. I disconnected all the top parts and all the attached hoses underneath, and only then it was possible to remove it.

Sure enough, there was enough accumulated debris to nearly block up the waste water outlet, which connects to the drain pump. Still left in the machine was a clear plastic rectangular box, the pressure switch assembly. It had some internal galleries and two rubber hoses that went back to the sump housing. It also housed the water level and the water overfill level pressure switches.

I found one gallery and its rubber hose full of black sludge. There was also black sludge in a side compartment of the sump housing. Perhaps this was an accumulation of coal dust, blown in through the back gauze door over the years. I remember Freda had a habit of leaving the dishwasher door open, until the next load was ready to be put through. Eventually all the black sludge was cleaned out and the sump housing and pressure switch assembly were refitted back into the machine.



~FREDA THEN TOLD ME, "I DON'T SEE HOW LEAVING THE STOP COCK OFF COULD HAVE CAUSED ALL THESE PROBLEMS..."

Serviceman's Log – *continued*

The water sensors would now faintly click when their rubber connecting hoses were gently blown through. All the rubber hoses were reconnected and all the upper parts were refitted to the sump housing. The dishwasher was turned on again but the drain pump was still pumping out water at the same time as it was trying to fill up with water; very strange indeed.

I went onto the internet but I was unable to find any reference to this particular fault but I found the correct method of entering into the test mode. This involves pressing the "Program/Clear" and the "Start/Pause" pushbuttons together for two seconds while switching on the Power switch.

Then you can use (mainly) the 'Program/Clear' pushbutton to step through the various sections of the test schedule. Earlier on, you will find (stored in the memory) up to the last three error codes. As you go further down the schedule, each machine function can be directly turned on.

These are displayed as item numbers 4 through to 10. The numbers of interest to me were item 6 – inlet valve open and item 5 – drain pump on.

I stepped through to (5) and found that the drain pump would run. However, when I went to 6, the water inlet solenoid valve would operate together with the drain pump. So it also appeared to have a fault on the control PCB, perhaps around the microprocessor.

With the power turned off again, I removed the control module out of the dishwasher door and there was evidence of bush cockroach ingress. Both the internal PCBs were removed out of the housing and carefully washed down with alcohol and then air dried out in the sun. But after reassembling and refitting the module, the fault was still there.

So back to the internet and there were two options available on eBay: Purchase an exchange control module for about $94 or a new one for about $170. It was now time to consult the management, ie, Freda. Apparently the existing control module was already a replacement unit. This was done a number of years ago (as a goodwill gesture) beyond the normal warranty time.

Ironically, the previous control module had also failed due to bush cockroach ingress. Freda then told me "I don't see how leaving the Stop Cock turned OFF could have caused all these problems you have found. I don't want a reconditioned Control Module put into my machine, as it probably won't last, and I don't want to spend the money on a new one".

However, there was another possible option to save face. Find a written-off machine at the recyclers and take out the control module, with the hope that it was still functional. That way I might have a good chance of getting the dishwasher fully operational again.

After several months, an Electrolux/Dishlex dishwasher did turn up at the recyclers and since it had been assigned to go onto the steel scrapheap, I was allowed to remove the control module. After getting it back home, I dismantled and cleaned the module and any suspect joints were resoldered on both the PCBs.

On the next trip to Freda's house, I fitted this module into the dishwasher door and put the machine into the test mode and now correctly started to fill with water. The dishwasher was then put through the quick cycle successfully. Freda eventually came out from her afternoon nap and wanted to know "what are you doing?" I said that I was testing the dishwasher and it is now working properly. "See, I told you there wasn't much wrong with it"! Now that's a real love job!

Gas igniter repair

This story from Geoff H., in Littlehampton, SA, involves the repair of a gas igniter for a 4-burner gas stove-top.

My son asked if I would have a look and see if it was possible to repair the gas igniter. There was no brand name on either the hotplates or the igniter box. So the first challenge was to dismantle the hotplates. Often it is as easy as pulling off the control knobs, removing the trivets, lifting off the gas burners and unscrewing a large nut off each burner so the complete top can be removed.

This exposes all the gas pipes, the igniter box and the wiring. The main thing to be careful of is lifting the top over the ceramic plugs that feed spark to the burner so as not to damage them. Normally it is easy but this one was not like that.

For this one you have to be a contortionist inside the cupboard below to remove two screws from each side then everything tends to fall down on top of you. It was definitely a two-person job. Anyway we got the igniter box out and I took it home to attempt a repair.

The first thing I noticed was that the momentary switch which activates it was stuck down. I was expecting a small transformer powering a simple timer type circuit to generate a pulsing low voltage spark into an ignition type coil, as these hotplates would be about 25 years old.

Instead, 230VAC was connected to a bridge rectifier to charge a capacitor via a resistor. From the capacitor the supply was connected a gas discharge surge arrestor to the ignition coil. So when the switch was pressed the capacitor charges up to the flashover point of the arrestor, induces a spark in the coil and the process continues while ever you press the button. It did not take long to replace the stuck down momentary-contact switch.

I was looking for a ground return for the spark but there wasn't any. Instead it uses the other leads as its return. Clever. I then tested it using my small 12V DC to 230VAC inverter. I did this as I want to isolate it from the 230VAC mains supply, being aware that it's potentially dangerous. Anyway it worked so I returned it to my son and he installed it back into the hotplates. But it still didn't work. What was going on?

After further investigation I found that someone must have disconnected the Active lead in the junction box to stop it working continuously because of the stuck momentary contact switch. I wonder how many years it had been in that condition.

Technics SU-Z400 amplifier

Japanese hifi gear from the mid-1980s was certainly built to last but 30 years later, it's not unusual to encounter faults. J. L., of NZ recently brought a dead Technics SU-Z400 stereo amplifier back from the dead but it was quite a battle . . .

I had been looking for a basic amplifier to play music in our games room and recently came across a Technics SU-Z400 power amplifier. It looked like it would do the job, it cost nothing and it still had the original owner's manual with it.

This amplifier is a pretty solid unit with a large, heavy power transformer

and a hefty heatsink. In short, it was typical of the well-built Japanese electronic gear from the 1980s. Inside it is based around an STK2058-4 stereo power amplifier IC and the manual claimed around 60W RMS per channel at 0.02% THD.

I duly plugged the unit in, applied power and got nothing; no sound, no indicator lights and no signs of life whatsoever. There wasn't so much as a sausage from this rather nice-looking amplifier that still appeared to be in good nick.

Now I'm the sort of person who will have a go at fixing virtually anything before writing it off as scrap, especially seeing how much gets thrown away these days due to simple faults. So no problem, I thought, it's probably just a blown fuse.

The unit came apart easily and I quickly discovered that the fuse was OK. What's more, power was reaching the primary winding of the hefty power transformer but nothing was coming out from the secondary leads. I immediately switched it off and reached for my multimeter. A quick continuity check showed that the primary winding was open circuit. Ouch!

The transformer carried an SLT5-M408 part number and appeared to have multi-tapped secondary windings. In addition, there is a switch on the rear of the amplifier that appears to change the secondary voltage depending on the impedance of the speakers connected.

I figured that the transformer was rated at somewhere around ±35V and possibly up to 300VA. I had some similarly-rated parts in my junk box but unfortunately none of them fitted into the confines of the chassis.

At that point, I mentally wrote the unit off as junk. And then, some time later, I recalled that some transformers I'd come across had thermal fuses built into them. Could that be the case here?

I removed the transformer and unsoldered the PCBs from its terminal pins. Some very careful cutting into the transformer's insulation then revealed a small thermal fuse tucked inside (without any markings) and sure enough, it was open circuit! Fortunately, the primary winding beyond that appeared was intact, according to the multimeter.

I took a guess and replaced the fuse with one rated at 125°C. I then reassembled everything, including tediously wrapping the windings in a new layer of tape.

This time. when power was applied, the input selector display and source LEDs lit up and all looked to be well! And so, with the transformer now transforming and the lights lighting, I duly connected a signal source and a pair of speakers and got . . . nothing. There wasn't even a faint hiss from the speakers with the volume turned all the way up.

At that point, something in my mind recalled the law of diminishing returns but I'd already come this far and after all, it was just a simple amplifier. How hard could it be?

Studying the main PCB showed a pretty conventional power amplifier and power supply, along with some other parts surrounding a relay. I traced the PCB tracks from the relay and this revealed that the relay switched the speaker outputs, so it was likely to be a form of protection circuit.

The relay itself was controlled by IC601, a TA7317P. A quick Google search revealed that this was indeed an amplifier protection IC with de-thump and DC detection. Connecting a speaker to the input side of the relay (accessible from the top of the PCB via R411 and R412) resulted in crystal-clear audio, so the protection circuitry looked like it might be the culprit.

Further PCB track tracing now revealed that some of the pins on IC601 weren't actually used. The DC detection pin was connected via isolating resistors to both outputs of the power amplifier IC (IC401), as well to the emitters of transistors Q621 and Q622 which appeared to make up a current detection circuit on the output of each channel.

The current detection outputs were then both fed via D602 into Q601 and Q602 which formed a latch, the output of which was also connected to IC601's DC detection pin (pin 2). This arrangement was likely there to ensure that the load remained disconnected once an overload condition had been detected.

I checked the voltage at the input to this latch circuit (collector of Q601 and base of Q602) and it was at -30V DC, as was the output. I figured that this -30V DC was likely to trigger the DC detection circuit in IC601 and cause it to disconnect the speakers.

In order to check if this really was the problem, I desoldered R605 which effectively disconnected the overload protection circuit and switched on. This time, the relay clicked in after a few seconds and sound burst forth from the speakers!

At that point, I took a punt and replaced both Q601 and Q602, figuring that one of them was probably leaky. I didn't have the original types on hand (2SA1015 and 2SC1815) so replaced them with a BC556 and a BC546 respectively, as they were the closest equivalents I had on hand. The only trick here was bending their base and collector pins into new positions to match the PCB.

Finally, with everything back in place the amplifier fired up and worked perfectly. Job done, you say? Not quite; Murphy made sure that the problems didn't end there!

After it had been running for about half an hour, the speakers suddenly crackled and then cut out completely. As I investigated the cause, I noticed the sound intermittently returning, along with accompanying relay chatter from the amplifier.

My first thoughts were that the transistors I had swapped in weren't quite right but on further reflection, a temperature-related cause seemed the more likely at this point. Close examination revealed some slightly dodgy solder joints around the protection circuit. I reworked all of them, along with some other suspects around IC401, the main amplifier IC.

After all that work, the amplifier hasn't skipped a beat since! Was it worth it for such an old unit? I think so – it sounds good and hasn't me cost anything apart from some time. The resale value of some of this vintage gear is on the rise too. SC

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

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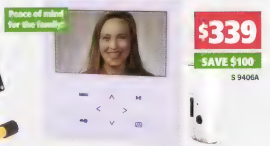

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Powerhouse® 7 Stage 12V High Output Battery Charger

This new model offers support for batteries up to 300Ah with an output current up to 12A! 7 stage charging delivers the appropriate charge current to maintain best performance & battery life. Can also recover deeply discharged cells. Suits permanent connection, making it great for seldom used vehicles. Auto reconnect starts charging again as soon as you connect the unit to mains!

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Powershield Safeguard 750VA UPS. This quality UPS unit will prevent appliance damage caused by power fluctuations, PLUS keep power on during a blackout! Also protects phone lines. 2 year warranty.

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Provides mains power anywhere, anytime! Delivers pure sine wave AC power to difficult loads, such as laptops, & game consoles. USB charging output. 12V input, 150W continuous, 300W surge rated. 170x108x60mm.

Battery Health Analyser

Detects and analyses voltage, cold cranking amperes, resistance and cell condition in 12V lead acid cells. Easy connection and on-screen menu driven operation. Ideal for vehicle servicing or checking 12V SLA cells in battery backup systems.

12V DC PV Solar Charge Controllers

Ensures optimal battery charging cycles for both wet cells & sealed lead acid batteries. • Microprocessor controlled • Deep cycle mode • Panel & battery output status • Over charge & temperature protection • Low voltage disconnect.

TP-Link® Wi-Fi Mains Plug

Switch any connected appliance on or off remotely from anywhere in the world! Set schedules, monitor and control your appliances using the TP-link Kasa mobile app. "Away" mode can give the appearance of someone being at home when you are on holiday - a great burglar deterrant!

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Allows you to keep an eye on the output voltage and current from your USB port when charging.

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High 4.2A charging current. Great for tablets.

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3.5A dual USB output. Mains surge circuitry protects your appliances from damaging power fluctuations.

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Utilises the LM2596S and LM2577 to accept a 3.5-28V input and output 1.25-28V at a max current of 1A - ideal for projects where regulated power is required.

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We now stock genuine Anderson connectors!
The real deal with heavy duty interlocking design. Handles & dust caps also available - see web.

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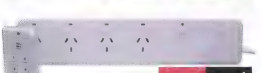
P 7835A	6AWG 50A	$9.95
P 7840A	2AWG 120A	$18.50
P 7845A	1AWG 150A	$27.50

5W Solar Charger Module

Produces up to 400mA charge current. Ideal for maintaining a 12V lead acid battery. 465W x 320H.



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3.7V 2600mAh. Features internal short circuit protection. 18.60 x 69mmL.

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Programmable via USB, this fun, decorative cube can create animations, scenes and 3D lighting effects. Includes 4 transition speeds and an array of selectable effects. White LEDs. Dimensions: 160x160x160mm

$159

K 8105

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Add a spectrum analyser to your audio project!

K 8102

NEW!

$74.95

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Give your homemade audio gear a high-tech look or upgrade existing equipment. This small and compact unit is ideal for panel mounting. 127 x 64mm white backlit LCD. Auto or manual range selection Measures: • Peak power RMS power. • Mean dB • Peak dB • Linear audio spectrum • 1/3 octave audio spectrum

Running Micro Bug Kit

Races toward nearby light sources! Features two open chassis sub-miniature motors with adjustable light sensitivity. Includes LED eyes. Requires 2xAAA batteries (S 4904 lithium $4.95 2pk). 100x60mm.

NEW!

$16.50

K 8112

The Tremor Effect Pedal Kit

Build your own analog effects pedal and tweak it you suit your needs! Controls level, depth, velocity, hard/smooth & true bypass. Tough diecast case

K 8122

NEW!

$99.95

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Build your own analog effects pedal and tweak it you suit your needs! Controls level, tone, symmetric/asymetric, distortion & true bypass. Tough diecast case

K 8124

NEW!

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A brightly coloured bug shaped robot which is always hungry for light and drives towards it. Features adjustable sensitivity, speed and walking motion. A great intro to robotics! Requires 2xAAA batteries (S 4904 lithium $4.95 2pk). 110x90mm.

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$23.95

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Clap On, Clap Off Relay Kit

Allows you to operate lighting simply by clapping your hands! 1 or 2 clap modes. Max relay output load 3A @ 24V.

Interval Timer Kit

For intermittent operation of circuits and equipment. Blinking light, slide projector control etc. 0.5-5s pulse. 2.5-60s interval.

NEW!

$11.50

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10 in 1 Solar Experiment Kit

Experiment Kit is a fun way to learn about solar powered projects. Printed instructions shows you how to build the 10 projects in a fun, safe and educational way. Includes all required parts.

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$26.50

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This kit is the first step into the world of modern electronics. Build your own circuits in a fun, safe and educative way. Contains a breadboard and all necessary components to start assembling your first circuit. 10 projects to build.

NEW!

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Shaking Dice Kit

No push button required, just give it a shake! Slowly rolls to a stop to show the final value. Requires CR2032 battery (S4999B $2.95)

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NEW!

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K 8116

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NEW!

$74.95

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Top deal for model train enthusiasts!

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Touchscreen DDS Signal Generator

It can produce sine, triangle or square waveforms from 1Hz to 10MHz, with ±0.005% frequency accuracy and it also has a sweep function. Its touchscreen LCD makes it very easy to drive and you can use it for audio or RF applications.

by Geoff Graham

This project combines a low-cost DDS function generator module with our touchscreen Micromite LCD BackPack module (first described in the February 2016 issue) to create a remarkably capable signal generator for the price. It can generate sine, triangle and square wave signals from 1Hz to 10MHz and you can specify that frequency with 1Hz resolution.

The Direct Digital Synthesiser (DDS) function generator module produces the actual waveforms while the Micromite controls it and provides an easy-to-use graphical user interface (GUI).

As well as generating the basic waveforms, this unit can also act as a sweep generator, allowing you to test the frequency response of filters, speakers, IF (intermediate frequency) stages (in superheterodyne radios) and more.

Other features include an adjustable output level, selectable amplitude modulation for the sine wave output and a selectable log/linear function for the frequency sweep.

Many would consider a signal generator to be the next most useful tool to have on a workbench after the multimeter and oscilloscope. While this device will not compete with a $1000 synthesised signal generator, it does provide the basics at a tiny fraction of the cost.

The DDS function generator module is fully assembled and can be purchased for about $15 on eBay or AliExpress. Combined with the Micromite BackPack (which uses fewer than a dozen components), you can build the whole project in under an hour and without breaking the bank.

Analog Devices AD9833

The AD9833 waveform generator IC is the heart of the signal generator module used in this project. It uses a DDS to generate its output.

Normally, it is difficult to digitally generate a relatively pure, variable frequency sine wave. Even the best Wein bridge (analog) oscillators are notoriously difficult to stabilise and can not be controlled over anywhere near the range of frequencies that this DDS unit can produce.

DDS involves a high-speed digital-to-analog converter along with a ROM lookup table, a phase accumulator and possibly digital interpolation to produce a relatively pure, variable frequency waveform.

The waveform shape can be changed by using a different lookup table or using a reprogrammable lookup table. In other words, DDS is somewhat similar to digital audio playback from a computer or compact disc but it normally operates at a much higher frequency.

We have a separate article on the AD9833 DDS IC and modules based on it elsewhere on this article, so please refer to pages 18-24 for an explanation of how it works.

Frequency precision

Because the AD9833 module uses a crystal-controlled oscillator to produce the sample clock, the precision of the output frequency is determined by the precision of the crystal.

With the specified module, this is better than ±50ppm (our prototype achieved about ±10ppm). This also means that calibration will not be required and the frequency will not drift with time.

For example, if you set the output to 1MHz, you can expect it to typically be between about 999.999kHz and 1000.001kHz, or in the worst case, between 999.995kHz and 1000.005kHz.

Another benefit of DDS is that the phase of the output will not change when the frequency register is updated and this in turn means that the output waveform will not have a glitch at the time of the change. This is vital for

Features & Specifications

General

Frequency accuracy: ±50ppm
Power supply: 4.5-5.5V DC at 350mA maximum
Output level: 10mV to 3V peak-to-peak (~3mV to ~1V RMS), 20Hz to 1MHz

Sinewave mode

Frequency: 1Hz to 10MHz with 1Hz resolution
Output level: as above up to 1MHz, reducing to 0.8V peak-to-peak at 10MHz
Amplitude Modulation: on/off (1kHz square wave)

Triangle wave mode

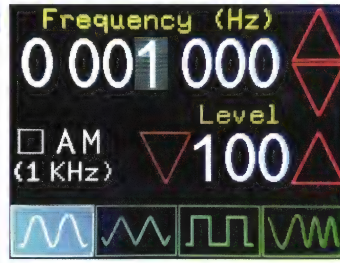
Frequency: 1Hz to 1MHz with 1Hz resolution

Square wave mode

Frequency: 1Hz to 1MHz with 1Hz resolution

Sweep mode

Waveform: sinewave only
Frequency start/stop: 1Hz to 1MHz with 1Hz resolution
Sweep period: 50ms, 100ms, 500ms, 1s, 2s
Sweep law: linear or exponential
Trigger output: 250µs positive pulse at start of sweep



Screenshot 1: this is the screen displayed for a sinewave output. The frequency can be changed by selecting a digit to change and touching the red up/down buttons. The signal level (expressed as a percentage of full scale) can be similarly adjusted. The check box marked AM will enable a 1kHz square wave amplitude modulation.

generating sweeps as it allows the frequency to be changed smoothly from one end of the sweep range to the other.

Because the waveform is digitally created with 1024 steps for each sinewave quadrant, the output is not perfectly smooth. The resulting harmonic distortion means that it is not quite good enough for noise or distortion measurements; its signal-to-noise ratio is about -60dB and its total harmonic distortion is typically 0.05%.

Having said that, it is more than adequate for general purpose tasks and the ability to quickly and accurately set the output frequency makes it a pleasure to use.

DDS module with gain control

The output of the AD9833 IC is about 0.6V peak-to-peak, so the function generator module that we are using includes a high-bandwidth amplifier based on the AD8051 rail-to-rail op amp. This can drive low-impedance loads (eg, 50Ω) and provide higher output levels (up to 3V peak-to-peak).

To control the gain of the output amplifier, the module uses a Microchip MCP41010 8-bit digital potentiometer which is under control of the Micromite (along with the AD9833). The bandwidth restrictions of the MCP41010 potentiometer result in a reduction in the output signal level above about 2MHz.

The output is still good for up to 10MHz but the signal level for sinewaves will be reduced and the triangle and square waves will look more like sine waves, so we have specified both of these to only 1MHz.

Micromite LCD BackPack

As with a number of our recent projects, this one is based on the Micromite LCD BackPack and relies on the touchscreen interface on the LCD panel to set the frequency and output levels – there are no switches or knobs.

The program is written in BASIC and because it is stored in plain text, you can see how it works and if you have the inclination, modify it to suit your personal preferences. For example, you can easily change the colours or add a special feature.

The Micromite LCD BackPack was described in the February 2016 issue of Silicon Chip and uses fewer than a dozen components. If you're reasonably experienced, you can build it in around half an hour. It includes a 3.3V regulator, the 28-pin Micromite PIC32 chip and touch-sensitive LCD screen. A complete kit is available from the Silicon Chip Online Shop. The February 2016 issue (printed or online) can also be purchased from the same source.

Note that if you want to try out the BASIC program for this project, you can do it on any Micromite with an ILI9341-based LCD panel connected; you do not need a DDS function generator module.

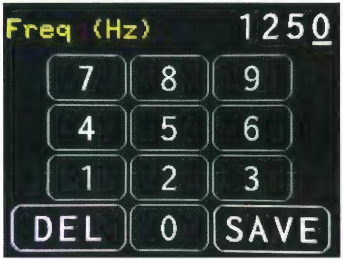
This is because the Micromite only sends commands to the AD9833 and MCP41010; it does not look for a response (and neither chip provides one anyway). So it won't know the difference; you simply won't get any signal output.

Driving it

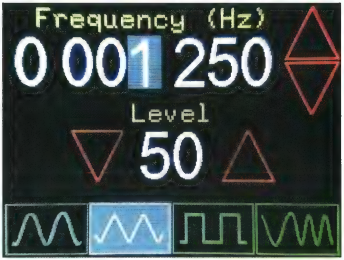
In operation, the signal generator is quite intuitive, with everything controlled via the colourful touchscreen LCD panel. Probably the best way to appreciate this is by looking at the screen shots.

At the bottom of every screen are four touch-sensitive icons which are used to select the operating modes: sine, triangle, square wave and sweep. Touching one of these will immediately switch to that mode.

Starting with the sinewave mode (shown in Screenshot 1), the frequency is adjusted by touching the red up/down buttons on the right of the frequency display. The least significant



Screenshot 2: you can enter a precise frequency or signal level by touching and holding the frequency or level display. This keyboard will then appear so you can enter the value. The DEL key deletes the last number entered and the SAVE button saves the value and return to the main screen.



Screenshot 3: the screen for generating the triangle waveform output is similar to that used for sinewaves. Along the bottom of the screen, the four touch sensitive icons are used to select the four operating modes – sine, triangle, square wave and sweep.

digit that you want to change can be specified by touching that digit and it will then be highlighted in blue.

A single touch on either the up or down buttons will increment or decrement the frequency but if you hold the button down, the frequency will increment or decrement with increasing speed.

While you are adjusting the display in this way, the output frequency will follow in real time so it is easy to scan through a range of frequencies to find the one that you want.

If you want to simply jump to a specific frequency, you can touch and hold a digit on the display and an on-screen numeric keypad will pop up, allowing you to directly key in the frequency that you want (see Screenshot 2).

Touching the SAVE button on this keypad returns to the main screen with that frequency set while the DEL button will delete the last digit entered.

The process to adjust the signal level is similar although you do not need to select a digit as the up/down buttons will always change the least significant digit.

Touching a digit in the level display will also take you to a numeric keypad where you can enter a specific level in the range from zero to 100% of full scale (about 3V peak-to-peak).

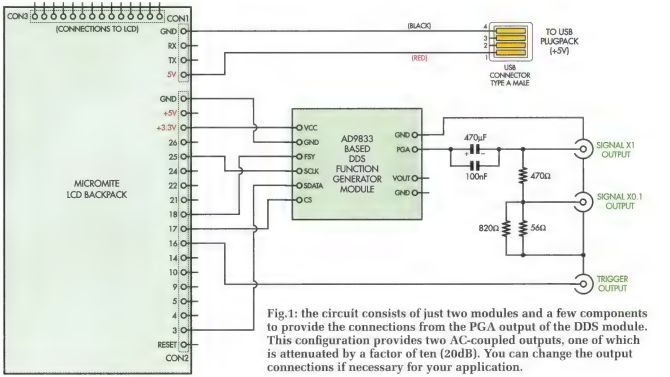
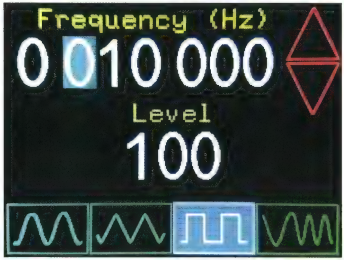
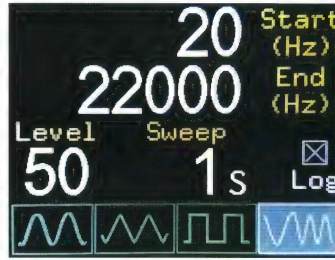


Fig.1: the circuit consists of just two modules and a few components to provide the connections from the PGA output of the DDS module. This configuration provides two AC-coupled outputs, one of which is attenuated by a factor of ten (20dB). You can change the output connections if necessary for your application.



Screenshot 4: the DDS module does not allow you to change the level of the square wave output so this is fixed. Frequency selection is the same as the other modes – the frequency is changed by selecting the least significant digit to change and touching the red up/down buttons.



Screenshot 5: the sweep output screen allows you to select the start frequency, end frequency, signal level, the sweep time and whether an exponential sweep is required. Touching entries like the start frequency makes a numeric keypad appear so you can key in the value that you want.

The sinewave screen has a check box for turning on or off amplitude modulation at 1kHz. This simply modulates the output with a 1kHz square wave and is useful for signal tracing in AM radios, both broadcast and shortwave, up to 10MHz.

The triangle waveform screen is similar to sine except that it does not provide an AM facility (see Screenshot 3). The square wave screen (shown in Screenshot 4) is also similar to the other two except that you cannot change the signal level (the MCP41010 digital potentiometer is not suitable for attenuating square waves).

All the changes that you make, including the waveform selection, are automatically saved in non-volatile memory and are recalled on power up. This means that when you turn on the signal generator, it will start up with exactly the same settings that you were using the last time.

Sinewave sweep

The sweep screen (Screenshot 5) uses a different screen layout. To select the start and end frequencies, you simply touch the frequency that you need to change and enter the specific frequency on the pop-up numeric keypad. You can select any frequency that you wish so you could even sweep all the way from 1Hz to 10MHz if you wanted to.

The output level is selected in a similar way, just touch the level display and a numeric keypad will pop up allowing you to enter that setting.

The sweep period works slightly differently; it will change every time you touch it, allowing you to step from a 50ms sweep time up to two seconds before wrapping around to 50ms again. Normally, the frequency sweep is performed in a linear manner with time but you can select an exponential (ie, inverse log) sweep with the "Log" check box.

With a linear sweep, it would take twice as long to go from 200Hz to 400Hz as it would from 100Hz to 200Hz. With an exponential sweep, it takes the same amount of time to go from 200Hz to 400Hz as it does from 100Hz to 200Hz, as both require a doubling in the output frequency.

This sounds more natural to human ears as doubling the frequency is equivalent to going up by one octave on a musical instrument.

The swept output is always a sinewave and at the start of the sweep, the Micromite generates a 250µs positive-going pulse on its pin 16 output, which is connected to the trigger output socket.

This signal can be used to trigger an oscilloscope so that it can lock onto the start of the sweep cycle for analysing the frequency response of a circuit or device.

Circuit details

Because the signal generator essentially consists of just two packaged modules connected together, the circuit is quite simple, as shown in Fig.1.

There are six connections between the LCD BackPack and the DDS function generator module. These are for power (+3.3V and ground), the serial data lines to the DDS (DAT and CLK) and two additional signals: FSY, which when pulled low selects the AD9833 DDS chip as the recipient of serial data and CS, which similarly is pulled low when the MCP41010 digital potentiometer is being sent a command via the serial bus.

The DDS module can run from 5V but we are using the regulated 3.3V supply rail from the Micromite LCD BackPack to avoid possible problems caused by potential noise from the output of a 5V USB charger. This noise can upset the AD9833 and MCP41010 ICs which need a clean power supply.

There are two outputs on the DDS module. One is labelled V_{OUT} and this is a fixed direct-coupled output from AD9833 waveform generator itself (about 0.6V peak-to-peak). But we are using the PGA (programmable gain amplifier) output of the module and it is AC-coupled to two RCA sockets, one at the full output level and the second attenuated by a factor of 10.

Combined with the MCP41010 digital potentiometer in the DDS module, this gives an output range from 10mV to 3V peak-to-peak (equivalent to 3.5mV to 1.06V RMS).

The use of the 470µF coupling

capacitor means that the output is usable to below 10Hz even into a 600Ω load. The parallel 100nF capacitor caters for higher frequencies, essentially bypassing any internal inductance of the larger capacitor.

The output from the module will swing from a little above ground to some maximum voltage determined by the MCP41010 digital potentiometer, below 3.3V.

If you will be primarily using the signal generator for testing digital circuits, you might prefer to dispense with AC-coupling and use DC coupling instead. You could even install a toggle switch to switch between these modes.

Similarly, you could use a switch to select different output attenuation levels if you wish. And you might consider using BNC sockets instead of the RCA sockets that we used.

The trigger output has simply been connected to output pin 16 of the BackPack. You may wish to include a low-value series resistor (eg, 1kΩ or less) to protect the BackPack from static discharge or accidental application of voltage to this terminal; it should not affect the trigger signal greatly.

Purchasing the right module

If you search eBay or AliExpress for "AD9833", you will find plenty of DDS modules (over 100 hits). However, you must be careful to purchase the correct module – there are a number of variations available and the firmware is written specifically to suit the module that we have pictured here.

It will probably not work with other modules, even if they also use the AD9833. So, check that the photograph matches perfectly and do not purchase anything different. Here is one which should be suitable:

www.aliexpress.com/item/2-3-5-5V-Signal-Generation-Module-Triangle-Sine-Wave-Signal-Source-IC-Integrated-Circuit-Square/32724505169.html

Many of the photos on eBay show the module with the I/O connector and SMA output socket already soldered to the board but all the vendors that we purchased from supplied these two components separately. We did not find the SMA socket necessary in our application but you could fit it if you want to.

Construction

Construction mostly involves assembly of the Micromite LCD BackPack and then mounting and connecting the DDS function generator module.

The BackPack PCB is silk-screened with the component placement and values so it is simply a case of populating the board and plugging it into an ILI9341-based LCD panel.

We suggest you use the 2.8-inch version. The February 2016 issue of SILICON CHIP, which described the Micromite LCD BackPack, fully covers this aspect.

If you have a PIC32 chip that's already programmed with the MMBasic firmware then you will need to set up the LCD panel for display and touch, then load the BASIC code into the chip using a serial console. A detailed explanation of how to do this is provided in the Micromite User Manual and the February 2016 issue of SILICON CHIP.

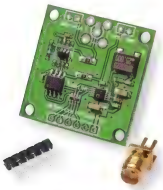
However, if your PIC32 chip is blank, you can load MMBasic and the code for this project simultaneously by programming it with the file "SigGenerator.hex", which can be downloaded from the SILICON CHIP website (along with the BASIC code). You will need a PIC32 programmer such as the PICkit 3 or the cheap DIY PIC32 programmer described in the November 2015 issue.

If you do not have such a device, you can simply purchase a fully programmed microcontroller from the SILICON CHIP shop. Regardless, if your chip is programmed with "SigGenerator.hex", all that you need do is plug the chip into its socket and connect the DDS module and you are ready to go.

The only point that you need to be aware of is that the touch calibration in the above firmware was done with a standard LCD panel. However, yours might require re-calibration if it is significantly different from the one that we used.

This can be done by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and running the calibration routine by issuing the "GUI CALIBRATE" command.

For further information, see the February 2016 BackPack article or



The Signal Generator is based on this pre-assembled DDS function generator module which uses the Analog Devices AD9833 to generate the signal. It's amplified by an AD8051 high-speed op amp while a Microchip MCP41010 digital potentiometer controls the gain.

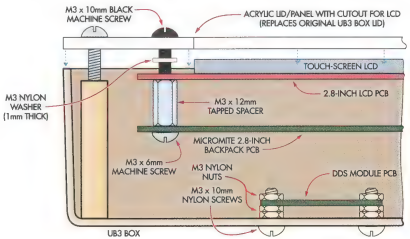


Fig.2: the DDS module is mounted in the bottom of the box using M3 machine screws, nuts and Nylon nuts as spacers. By contrast, the BackPack is attached to the underside of the laser-cut lid. The wiring is not shown in this diagram.

the Micromite User Manual (which can be downloaded from the SILICON CHIP website).

Putting it in a box

The Micromite LCD BackPack fits neatly into a standard UB3 plastic box, as we have done with similar projects based on the BackPack.

The easiest way is to use the laser-cut acrylic front panel which replaces the standard lid supplied with the box and is normally supplied with the kit. This provides a neat looking assembly with the display and BackPack securely fastened.

You can also purchase this panel from the SILICON CHIP shop separately in a number of different colours including black and clear.

Note that this panel is thicker than the lid supplied with the UB3 box so the self-tapping screws supplied with the box may not be long enough. In that case, replace them with No.4 x 10mm self-tapping screws.

The first stage of assembly is to attach the LCD panel to the acrylic lid using an M3 x 10mm machine screw, a single M3 washer and an M3 x 12mm tapped spacer at each corner.

This arrangement ensures that the surface of the LCD sits flush with the acrylic lid. Then, the backpack should be plugged into the LCD and fastened by M3 x 6mm machine screws to each spacer. Details of the full assembly is shown in Fig.2.

The LCD and the BackPack require a 5V power supply with a minimum capacity of 300mA. For this, you can use a 5V plugpack or a USB charger.

You can also find USB Type A to DC charging cables on eBay or AliExpress, which circumvents the need for cable rewiring. If you are using a plugpack, make sure that it is regulated and that its unloaded output does not rise above 5.5V as this could cause damage.

Parts List

1 2.8-inch Micromite LCD BackPack module; see the February 2016 issue of SILICON CHIP (kit available)
1 DDS function generator module with AD9833, AD8051 and MCP41010 ICs (see text and photos)
1 UB3 "jiffy" plastic box
1 pre-cut plastic lid to suit BackPack and UB3 box (normally included with kit)
1 USB charger plus USB cable with a male Type A connector on one end (alternatively, a USB Type A to DC connector charging cable)
OR
1 5V regulated plugpack
1 matching chassis-mount DC barrel socket
6 flying leads (120mm) with single pin female headers (DuPont connectors) on each end (Jaycar WC6026, Altronics Cat P1017)
5 flying leads (120mm) with single pin female headers (DuPont connectors) on one end and bare wire on the other
1 6-pin right-angle male header
4 No.4 x 10mm self-tapping screws
4 M3 x 10mm tapped Nylon spacers
8 M3 x 10mm machine screws
4 M3 x 6mm machine screws
4 M3 Nylon washers
12 M3 Nylon nuts

Capacitors
1 470µF 16V electrolytic
1 100nF multi-layer ceramic

Resistors (all 0.25W, 5%)
1 820Ω 1 560Ω 1 56Ω

For a USB charger, a suitable power cable can be made by cutting off one end of a standard USB cable (retaining the Type A connector on the other end) and soldering the free end to a suitable DC power plug. The red wire in the USB cable (+5V) should go to the centre pin of the plug and the black to the sleeve. The other two wires (the signal wires) can be cut short as they are not used.

A matching DC socket for incoming power can be mounted on the side of the UB3 box. Two flying leads from this socket should be fitted with female header sockets (also known as DuPont connectors) which fit over the BackPack's power header pins (CON1). Fig.3 illustrates the complete assembly.

The DDS function generator module can be mounted on the base of the UB3 box using four M3 machine screws and nuts. Use Nylon M3 nuts as spacers between the base of the box and the module.

You need to select a spot for the module that will not foul the underside of the BackPack PCB, particularly CON1 and CON2 which extend close to the bottom of the box.

Finally, connect flying leads from

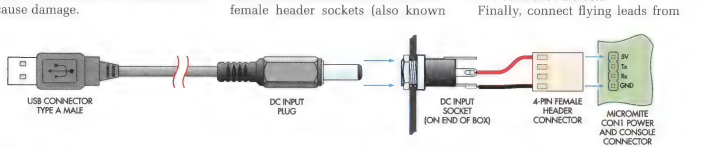
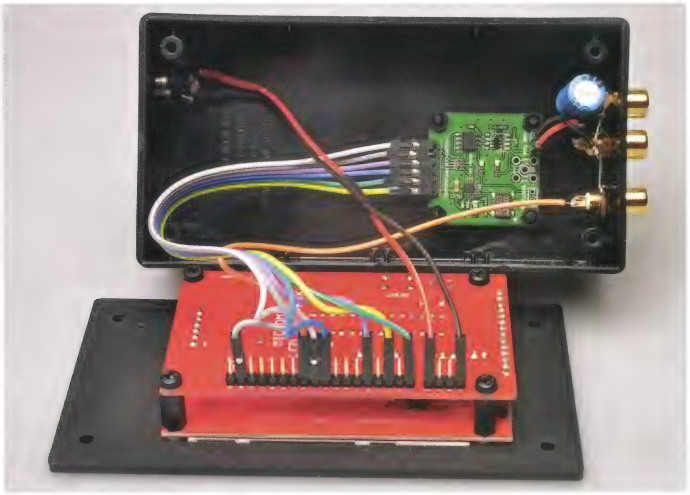


Fig.3: the Signal Generator is powered from a standard USB plugpack charger. To make a suitable power cable, cut one end off a USB cable (maintaining the type A male connector at the other end) and solder the red wire to the centre terminal pin of a DC plug and the black wire to the outer barrel connection. The matching DC socket is mounted on the side of the UB3 box and is connected to CON1 on the BackPack PCB.



Interior view of the Touchscreen DDS Signal Generator showing the connections made from the Micromite BackPack to the module and internal connectors. You do not have to solder the extra through-hole components the way we did, as the UB3 jiffy box provides a fair bit of clearance.

the module to the required pins on CON2 on the BackPack and from the DDS outputs to the RCA (or BNC) connectors.

The most convenient method of mounting the output capacitor and resistors is to solder them directly onto the RCA/BNC connectors. Fig.4, overleaf, provides a convenient summary of all the connections to the DDS module.

We suggest that you wire up the connections from the module to the BackPack using leads with female header sockets (DuPont connectors) at each end. These will simply plug onto the headers on both modules and this makes it easy to remove and/or

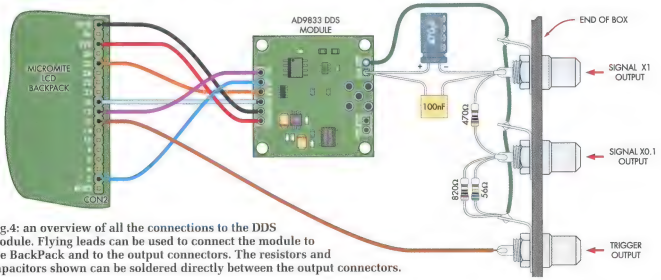


Fig.4: an overview of all the connections to the DDS module. Flying leads can be used to connect the module to the BackPack and to the output connectors. The resistors and capacitors shown can be soldered directly between the output connectors.

replace the module if necessary.

Altronics have suitable pre-assembled leads (Cat P1017) as do Jaycar (WC6026) or search eBay or AliExpress for "DuPont Jumper".

Testing

Before connecting the DDS function generator module, confirm that the Micromite LCD BackPack is working correctly and has been programmed with the BASIC code. The testing procedure is described in the Micromite User Manual and also in the February 2016 issue.

Then it should simply be a matter of connecting the DDS module and checking its output. If it does not appear to be working, your first action should be to carefully re-check each connection. Then measure the voltage across the pins marked V_{CC} and GND on the module, which should give precisely 3.3V.

Remember that the module does not provide any feedback to the Micromite so the LCD might show the frequency, level etc and look like it is working but this does not mean that the module is actually alive and reacting to these commands (it is a one-way communication path).

If you have an oscilloscope or logic analyser, you can monitor the pins labelled FSY, CLK and DAT on the module.

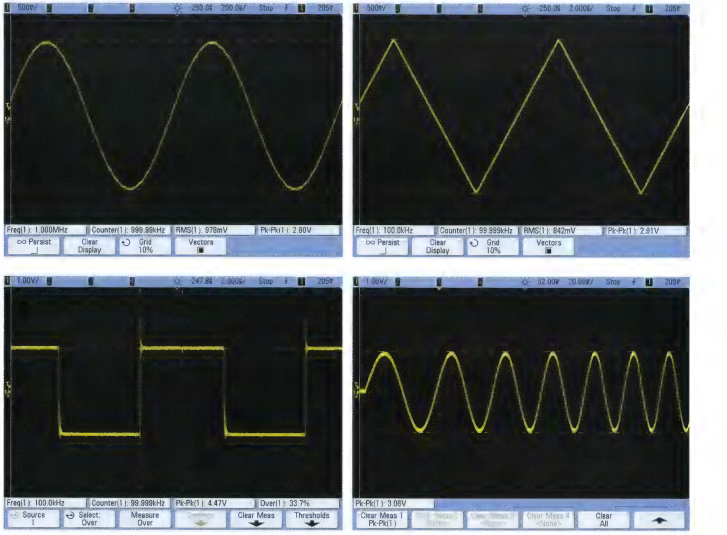
Every time you change the frequency you should see a burst of data on these pins. Similarly, the pins labelled CS, CLK and DAT will show a burst of data when the signal level is changed. If these are not present, re-check the Micromite LCD Backpack and its connections.

A final test is to connect a LED with a suitable current limiting resistor or an old fashioned moving-coil multimeter directly to the output of the module and set the signal generator to a 1Hz square wave.

You should see the LED or meter responding to the 1Hz output. If not, the simple option is to replace the DDS module. Scope 1-4 show waveforms that have been generated using the DDS Signal Generator.

Firmware updates for the Micromite and the BASIC software for the DDS Signal Generator will be provided on the SILICON CHIP website but you can also check the author's website for updates at:

http://geoffg.net/micromite.html SC



Scope 1-4: These scope captures show typical output waveforms. The sinewave output is reasonably smooth despite being digitally created; there is some harmonic distortion which means that you cannot use this project for precise noise and distortion measurements but it and the other outputs are quite suitable for general purpose tasks. The final scope capture shows a short sweep between 20Hz and 50Hz.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Two modifications to the Battery LifeSaver

In Ask Silicon Chip this month, reader Dave asked whether it would be possible to modify the Battery LifeSaver (Silicon Chip, September 2013) to switch the battery positive line, rather than the negative line, and also whether it could be configured to protect a battery from being over-charged rather than over-discharged. These two modifications show how it can be done.

In both cases, the onboard N-channel Mosfet is used to switch an external Mosfet with sufficient voltage and current ratings to handle the battery voltage (30V is sufficient) and load current, which depends on the application.

The first modification, shown in the circuit diagram of Fig.1 and wiring diagram, Fig.3, shows how to use an external P-channel Mosfet (Q2) to operate in a similar manner to the original LifeSaver, but with the battery positive terminal disconnected when it is flat, rather than the negative terminal.

An added 1MΩ resistor pulls the V- OUT terminal up to +12V when Q1 is off (ie, if the battery voltage is low). This terminal voltage goes down to 0V when Q1 switches on (ie, when the battery voltage is above the cut-out threshold).

When Q1 switches on, it pulls down the voltage at the gate of Q2 (P-channel) so when Q1 switches on, so does Q2. Thus current can flow from the battery positive terminal, wired to its source pin, through to the load at its drain.

To prevent battery over-charging, we want the LifeSaver to operate in the reverse of its normal mode, ie, so that it switches on when the voltage is below the threshold voltage and switch off when it is above, disconnecting the battery once it is fully charged. This is shown in Fig.2 and Fig.4.

To reverse its normal operation, we again wire up a Mosfet with its gate to the V- OUT terminal but this time, since it is an N-channel Mosfet (like Q1), this effectively inverts the logic. Thus it is switched off when Q1 is on and turns on when Q1 is off and the 1MΩ resistor pulls its gate up to +12V.

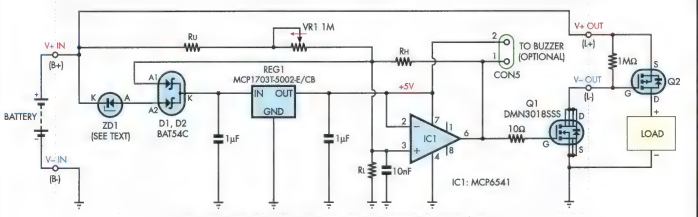


Fig.1: modifying the Battery LifeSaver to switch the positive battery line

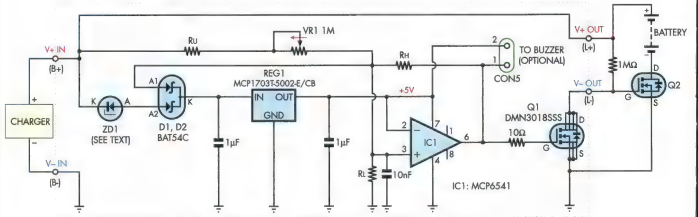


Fig.2: modifying the Battery LifeSaver to prevent battery over-charging

Note that since the charger is disconnected from the battery once the output of the charger exceeds the threshold (which may be set at say 14.4V), if it's a smart charger, it may switch off when the battery is disconnected.

A "dumb" charger will simply produce an even higher voltage, thus the LifeSaver will leave the battery disconnected until you switch the charger off yourself. Either way, charging is effectively terminated once the target voltage has been reached.

Nicholas Vinen,
Silicon Chip.

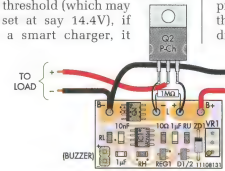


Fig.3: modifying the Battery LifeSaver to switch the positive battery line

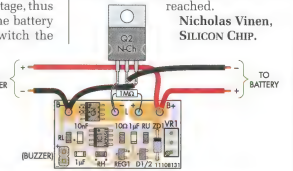


Fig.4: modifying the Battery LifeSaver to prevent battery over-charging

Measuring weight using Arduino

Digital scales have come down in price significantly and have now almost totally displaced the simple mechanical scales once used to measure body weight or weigh ingredients for cooking, etc.

It is now possible build a 5kg scale with an accuracy of around ±1g, using an Arduino, an instrumentation amplifier module and a strain gauge-based "load cell". This could be used as part of a robot which needs to deliver a certain weight of liquid, for example.

In fact, you can use various different sizes of load cells using the same method, including those large enough to weigh a person. The load cell comprises four strain gauges on a flexible arm which are connected in a Wheatstone bridge configuration.

Physically, the load cell is built as shown in the corner of the circuit diagram, with two strain gauges along the top of the "binocular beam" and two along the bottom. When a load is placed on the free end of the beam, the beam flexes and the upper two strain gauges are in tension while the lower two are placed in compression. This affects their resistance.

As shown in the circuit diagram at left, the Wheatstone bridge is effectively two resistive dividers in parallel with the same voltage across both (between E+ and E-).

Due to the way it is arranged, as the load on the beam increases, the voltage at the S+ terminal increases, due to the lower resistance of the upper strain gauge under compression and the greater resistance of the lower one under tension.

At the same time, the voltage at the S- terminal decreases, as the strain gauges are effectively swapped in that side of the bridge.

The change in voltage is quite small so you need an amplifier to get a sensible reading from a microcontroller and it needs to accurately remove any "common mode" signal which might occur due to changes in temperature and so on.

In other words, if the voltages at the S- and S+ terminals both rise at the same time and by the same amount, this should result in no change in the output of the amplifier as this is due to a change in the supply voltage or the properties of two adjacent resistors (eg, due to a temperature shift), not a change in the load weight.

Instrumentation amplifiers are designed for this type of measurement so we are using an HX711 which includes an inbuilt 24-bit analog-to-digital converter (ADC). This is far more precise than the 10-bit ADC in an Arduino and other common microcontrollers.

The HX711 also includes a two-input multiplexer, allowing two load cells to be monitored, plus a programmable gain amplifier to control its sensitivity and a regulator to control the voltage applied to the load cell.

You get all that for less than one dollar, in a module that's easy to connect to an Arduino, so it's really the ideal way of interfacing with a load cell.

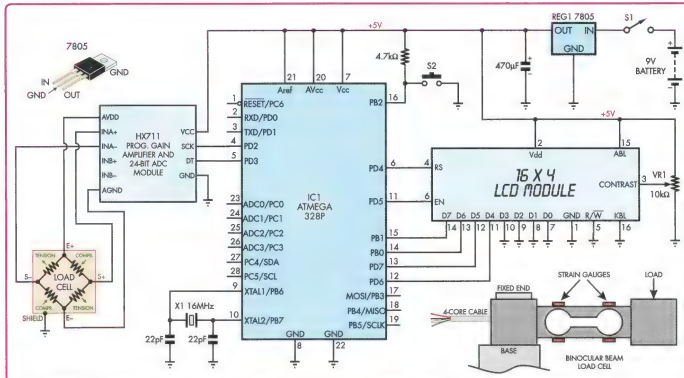
As well as the HX-711 module and load cell, the circuit comprises ATmega328 microcontroller IC1 (an Arduino or equivalent can also be used), a 4-line alphanumeric LCD to display the measured weight with a contrast adjustment potentiometer, a simple power supply and push-button S2 which is used to zero the readings. The whole thing is powered from a 5V rail derived from a 9V battery.

As you can see, the hardware is quite simple and so is the software, at around 50 lines total. It uses just two libraries, one called "HX711" which is used to get the data from the HX711 module and one called

continued next page

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the Silicon Chip on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au



"floatToString" which is used to convert the weight measurements to text, so it can be shown on the LCD. These are both included in the software download on the SILICON CHIP website, along with the Arduino sketch itself.

Its setup routine initialises the LCD, calibrates the scale and then goes into a loop where it measures the weight on the scale 25 times, averages the readings (for extra stability) and displays this on the LCD.

If S2 is pressed, the software detects that pin 16 (digital input D10) has been pulled low and it stores the current reading from the load cell, in order to zero the measurement. This can be used to initially set the scale to read zero as well as for tare readings (eg, measuring the weight of items in a bowl without showing the weight of the bowl).

If you want the displayed weight to update more rapidly, you can reduce the number of times the measurement is averaged by modifying the sketch.

Note that the software contains a hard-coded calibration constant which determines the relationship between the weight on the strain gauge and the voltage across it. This "calibration_factor" constant is defined as -7050 at the top of the code and has been found to work well with the load cell listed below (from China).

If using a different load cell, you would need to run the software, measure a known weight and then adjust the calibration constant to suit. For example, if you put a 1kg object on the scale (after zeroing it with S2) and got a reading of 565g, change the constant to -12478 (-7050 × 1000g ÷ 565g).

The load cell is available at: http://siliconchip.com.au/l/aac6

And the HX-711 module at: http://siliconchip.com.au/l/aac7

Bera Somnath,
Vindhyanagar, India. ($80)

Simple bird scarer stops tree damage

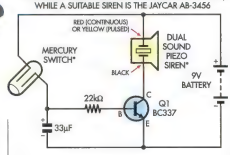
We have problems in spring and summer with parrots eating the seeds in one of our trees, dropping a big mess of leaves on our driveway. This circuit was developed in response, with the prototype placed in a sandwich bag to protect it from rain and hung on a flexible branch of the tree.

If a bird lands in the tree, the resulting motion triggers the mercury tilt switch, charging up the capacitor and switching on NPN transistor Q1, which powers the siren and generates a loud tone or series of tones to scare off the bird.

When placing the bag in the tree, the tilt of the mercury switch is adjusted to set the sensitivity to branch movement, allowing for movement when the wind blows.

It's powered by a 9V battery and is simple enough to be air-wired or built on a small piece of protoboard.

This could also be used to stop cockatoos from destroying flowering trees and shrubs, or any other time that animals making a nuisance of themselves can be detected by the deflection of plant limbs.



Roderick Wall,
Mount Eliza, Vic. ($35)

Keysight DSOX1102G Oscilloscope

Review by Nicholas Vinen

A few years ago, Keysight brought two new series of InfiniiVision oscilloscopes, named DSOX2000 and DSOX3000, at prices that were previously unheard of for the performance they offered. This was thanks to their MegaZoom IV integrated circuit which is basically the guts of a high-performance scope on a single chip. Now they've put that same IC into a more compact and even more affordable scope.

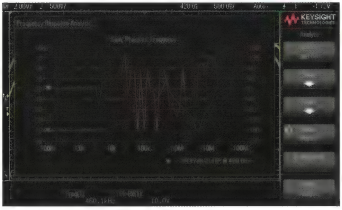
After reviewing the then brand-new MSOX2000 and MSOX3000-series scopes in the April 2011 issue, I was so impressed that I subsequently purchased an MSOX3014A 4-channel mixed signal oscilloscope to use at home. By comparison to the Agilent DSO7034A we were already using at the SILICON CHIP lab, it has less bandwidth and a smaller screen but was also considerably less expensive and included a lot of new features and what I still think is outstanding performance. It's also more compact.

Having just one modern DSO in our lab sometimes causes contention, so eventually I ended up bringing in my own scope and it isn't exactly a hardship when I end up relegated to the smaller unit. In fact, despite the screen size disadvantage, I think mine is somewhat nicer to use.

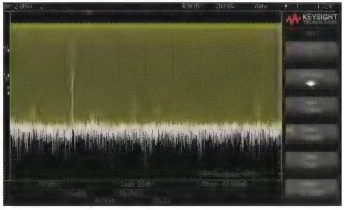
If you haven't read the 2011 review, to summarise, the MSOX2000 and MSOX3000 series scopes are the same size, with the same screen and look virtually identical. Both come with either two or four analog channels and a mixed-signal option with 8 digital channels for MSOX2000 or 16 for MSOX3000 series scopes. The main difference between the two is in the waveform update rate and the fact that the MSOX3000 offers more standard and optional features.

Until recently, the entry-level MegaZoom IV-equipped scope from Keysight was the MSOX2012A, with two 100MHz channels. At around $2500, we think it's good value but there are a lot of people who simply can't justify spending that much money on a scope. Hence the new DSOX1000 series, launched just last month, represented by the mid-range DSOX1102G reviewed here.

Note that the DSOX1000 series is distinct from the Keysight DSO1000A/DSO1000B models; the latter have been available for some time but do not use the MegaZoom IV IC and so



Scope 1: we found this Frequency Response Analysis feature tucked away in the "Analyze" menu. The blue trace shows the frequency response of the LC filter network connected between the arbitrary waveform generator (AWG) output and scope inputs, from 100Hz up to 25MHz.



Scope 2: using the scope's built-in Fast Fourier Transform (FFT) capability to analyse the 460kHz sinewave from the arbitrary waveform generator. You can see that the second harmonic (920kHz) and fourth harmonic (1840kHz) are the strongest. The other peaks are probably AM radio stations.

do not have comparable performance. The one advantage the A/B series models seem to have is the option for four channels; to get that with MegaZoom IV, you need to look at the DSOX2000 series.

Similarities and differences

Some of the similarities and differences between the DSOX1000 and DSOX2000 series scopes are immediately obvious. The DSOX1102G is clearly more compact than the DSOX2000 or DSOX3000 series, at 310mm wide, 170mm high (with feet retracted) and 140mm deep (including knobs and connectors). By comparison, my MSOX3014A is 380mm wide and 210mm high; its depth is similar.

The difference in weight is less than you might expect. The DSOX1102G is a relatively hefty 3.2kg while my four-channel MSOX3014A is only a tad heavier at 3.9kg.

Another difference that I immediately spotted is the lack of a logic probe interface on the front panel of the DSOX1102G. That's because there is no mixed signal option – it's a plain vanilla two-channel scope.

Powering up the DSOX1102G, the interface is immediately familiar. Despite the slightly smaller screen (175mm/7" diagonal compared to 225mm/9"), the resolution appears to be the same and once you get used to the different button layout on the front panel, its operation is familiar.

While some things have been rejigged, the interfaces and functions available on the 1000-series scope mostly parallel those on the higher-spec models and other than some of the more advanced options such as plotting using complex mathematical equations, nothing really seems to be missing.

Another difference I noticed immediately is that the fan on the DSOX1102G is a little louder than the fan on my MSOX3014A; not so much that it would drive you crazy but you certainly can hear the fan spinning, while the noise from the MSOX3014A is barely audible in a typical lab or workshop environment.

Acquisition performance of the 1000-series scopes is pretty much on par with the 2000-series scopes; both have a waveform update rate of around 50,000 per second, which is not quite as good as the 3000-series or 4000-series (at over 1 million per second) but it's still right up there for an entry-level scope. Like the 2000-series and 3000-series, the 1000-series scopes have the option for a single channel arbitrary waveform generator (AWG) output, which is quite handy to have.

The 1000-series also has an option for serial protocol analysis that's equivalent to the one available on the 2000-series. However, there is no waveform search option for the 1000-series; something that's nice to have but I personally rarely use it.

Interestingly, 1000-series scopes include standard features that cost extra on the more expensive models. This includes Digital Voltmeter (DVM) functionality, segmented memory and mask/limit testing.

Sampling rate is 1Gsample/second for 2-channel models and 2Gsample/second for 4-channel models which is more than adequate given the bandwidth choices are 50MHz, 70MHz and 100MHz.

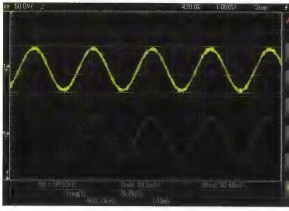
Educational models, accessories and upgrades

While we don't have a lot of details at this stage, there are special "cut-down" scopes in the DSOX1000 series for the educational market with smaller sample memories (100kpoints maximum rather than 1Mpoint) and no standard segmented memory or mask/limit testing features. These changes are unlikely to have much effect for educational use and we expect prices for educational models will be lower than the standard models.

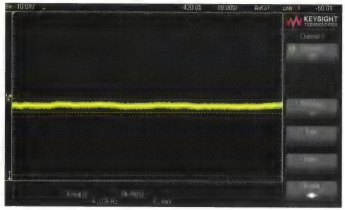
The DSO1000-series scopes are supplied with two suitable probes and a power cord. Presumably you will also get a user manual/CD although the sample unit we got to review did not have either.

Some time after I bought my MSOX3014A, I upgraded its bandwidth from 100MHz to 200MHz and added a number of extra features including power analysis and segmented memory, at a time when Keysight had a 2-for-1 upgrade sale on. This was a relatively painless process and the extra features have come in handy from time to time.

The DSOX1000-series scopes are also upgradeable, both in terms of bandwidth, memory and software features. The main difference is that they "top out" with lower specifications than the DSOX2000-series (which in turn, can't be upgraded as far as the DSOX3000-series) so upgrading after purchase can only take you so far before you have to buy a better scope.



Scope 3: another quite handy feature of the scope is the low-pass filter option. At top in yellow is the output of the AWG set for a sinewave at 10mV peak-to-peak using a 1:1 probe. Below it is the same waveform after having gone through a digital 1MHz low-pass filter.



Scope 4: shorting out the channel 1 probe and cranking up the vertical sensitivity gives this result, with bandwidth limiting enabled. This reveals the presence of a few millivolts of noise that could otherwise mask very low-level analog signals.

Conclusion

While there are a lot of compact, low-cost scopes on the market, many of which would undercut the Keysight 1000-series on price, we doubt if any of them could compete with the sheer performance of the MegaZoom IV chipset. So if you just need a basic two-channel scope, but want one with the speed and features of a much more expensive unit, you certainly should take a good look at Keysight's offerings.

Our only real criticism of the DSOX1102G applies also to the DSO/MSOX2000 series and DSO/MSOX3000-series (including my own personal scope), which is that its input noise is not particularly low. While you can change the vertical scale to 5mV/div with a 10:1 probe, the result is a rather thick trace (see Scope 4). In fact, on the DSOX1102G, when you go to 5mV/div, channel bandwidth limiting is automatically activated to reduce noise.

The practical effect of this is to make measuring low-level analog signals difficult. One simple solution is to use a 1:1 probe but then you have to swap probes depending on the signal you are measuring, which is a little frustrating.

Depending on how you use the scope, you may never run into this and you can also pretty much solve this by using "high resolution" mode (or averaging, for repetitive signals). But we would like to see future Keysight scopes pay more attention to reducing input noise for better sensitivity.

Regardless, we would have to say that the entire series of "InfiniiVision" scopes from Keysight is probably the most capable and well-rounded of any manufacturer, which is why we use them ourselves.

Pricing and availability

To get a price, enquire about one of these scopes or make a purchase, contact Trio Test & Measurement by ringing 1300 853 407 or e-mailing sales@triotest.com.au They are located at unit 4, level 1, 8 Century Circuit, Norwest Business Park, Baulkham Hills NSW 2153. SC

The back of the set is quite bare in comparison to the front. However, there is one USB and an optional LAN port tucked away on edge of the set which can be used to connect the scope to other devices, such as a computer.

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	IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13)	
	PC Birdies "2 chips – $15 pair" (Aug13), Driveway Monitor Receiver (July15)	
	Hotel Safe Alarm (Jun16), 50A Battery Charger Controller (Nov16)	
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)	
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13),	
	Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14)	
	Automotive Sensor Modifier (Dec16)	
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11),	
	Quizzical (Oct11), Ultra LD Preamp (Nov11), 10-Channel Remote Control	
	Receiver (Jun12), Revised 10-Channel Remote Control Receiver (Jul13),	
	Nicad/NiMH Burp Charger (Mar14), Remote Mains Timer (Nov14),	
	Driveway Monitor Transmitter (July15), Fingerprint Scanner (Nov15)	
	MPPT Lighting Charge Controller (Feb16), 50/60Hz Turntable Driver (May16)	
	Cyclic Pump Timer (Sep16), 60V 40A DC Motor Speed Controller (Jan17)	
	Pool Lap Counter (Mar17)	
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13), GPS Analog Clock Driver (Feb17)	
PIC16LF88-I/SO	LED Ladybird (Apr13)	
PIC16LF1709-I/SO	Battery Cell Balancer (Mar16)	
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10)	
	Sentinel (Feb-May12)	
PIC18F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)	

PIC18F4550-I/P	GPS Car Computer (Jun10), GPS Boat Computer (Oct10)
PIC18F27J53-I/SP	USB Data Logger (Dec10-Feb11)
PIC18LF14K22	Digital Spirit Level (Aug11), G-Force Meter (Nov11)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12), Touchscreen Audio Recorder (Jun/Jul14)
PIC32MX170F256B-50I/SP	Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor* Micromite LCD Backpack (either version) (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Low Frequency Distortion Analyser (Apr17)
PIC32MX170F256D-I/SP	44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost)
PIC32MX250F128B-I/SP	GPS Tracker (Nov13), Micromite ASCII Video Terminal (Jul14)
PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb-14), Digital Effects Unit (Oct14)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 15), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ12GP202-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11); Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
dsPIC33FJ64MC802-E/P	Induction Motor Speed Controller (revised) (Aug13)
dsPIC33FJ64GP306-I/PT	CLASSIC DAC (Feb-May 13)
ATTiny861	VVA Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)
ATTiny2313	Remote-Controlled Timer (Aug10)

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hard-to-get parts: DB-GH6, IRF9540, 150pF/250V capacitor and five SMD resistors

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hard-to-get parts: IC2, Q1, Q2 and D1

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(includes PCB, programmed micro and the hard-to-get bits including female headers, USB and microSD sockets, crystal, etc but does not include the LCD panel)

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with two 10mm M2 spacers & four 6mm M2 Nylon screws *(JUL 16)* **$5.00**

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04/17

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a toll kit.* If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/Shop* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
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DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	04108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	25108121	$20.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	09109121	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110122	$20 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$10.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SESMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103112	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-433MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
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RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
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SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp (Sept11)	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Gutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
L'il Pulser Mk2 Revised	JAN 2014	09107134	$15.00
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OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
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REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
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MULTI/SPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$40.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015		$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
8-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/5	$20.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101151	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101152	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60HZ TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	01107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC COMPUMAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$5.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATION/MASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
NEW THIS MONTH			
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50

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Vintage Television

By Ian Batty

Sony's TV8-301: the world's first direct-view transistor TV set

While TV sets were being made in huge numbers around the world in the late 1950s, they were all complex valve circuits typically driving 17-inch cathode ray tubes (CRTs). Portable transistor radios from Japan were well-known but there was no portable direct-view TV set. Then Sony produced an incredible new design, with an all solid-state motherboard and three daughter boards.

Amidst the ruins of postwar Japan, in 1947 young Masaru Ibuka and his friend Akio Morita set up Tokyo Tsushin Kogyo – Tokyo Telecommunications Engineering Corporation – ultimately to be known as Sony. Their first product was an electric rice cooker but the company quickly got into electronics, repairing radios, many of which had been stripped of their short-wave sections.

As in Nazi Germany, the Japanese government had wanted to prevent its citizens from listening to anything but local propaganda on Medium Wave and Long Wave. So Sony made a tidy profit with their first electronic gadget, a short-wave converter for broadcast-only radios. They moved on in the 1950s to making tape recorders using oxide coatings on a paper strip base.

Sony had acquired the tape-recording patent for ultrasonic bias from Anritsu, principally known today as an instrument company.

This allowed Sony to begin their progress in magnetic recording. Their instruments were adopted by the courts and schools, establishing the company as a prestigious, high technology manufacturer.

Following Ibuka's visionary trip to attempt to sign a licence with Western Electric, Sony acquired patent rights for the transistor and began manufacturing portable radios in 1955.

Preferring NPN transistors for their better high-frequency response, Sony were initially unable to produce working examples. In those days, the Bell Lab's research was "like the word of God". After much discussion, the research laboratory's head, Makoto Kikuchi, suggested laying aside Bell's experience.

Sony's labs then dropped Bell's preferred indium as a doping agent and substituted phosphorus. It soon paid off, allowing Sony to produce the transistors used in their first transistor radios.

Portable television receiver

Sony's approach to portable television design was far ahead of Philco, who had just beat them to market with their first set in 1959.

Rather than taking the Safari approach (described in the November 2014 issue: http://siliconchip.com.au/Issue/2014/January/Philco+Safari%3A+the+first+transistor+portable+projection+TV+set) with a compromise

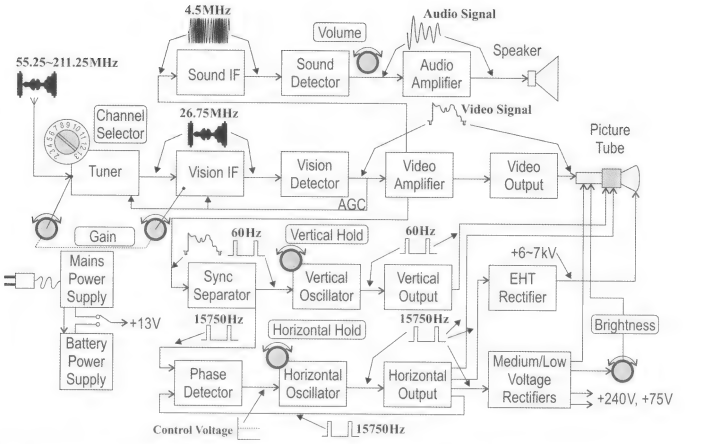


Fig.1: block diagram of the Sony TV8-301. This is the US version of the diagram, showing 60Hz field frequency and a 15750Hz (525 × 30) horizontal sweep frequency. Note that it also has the sound IF at 4.5MHz instead of 5.5MHz used in the PAL system in Australia.

design needing space-hogging optics, Sony built a "proper" portable television set, the TV8-301, with an 8-inch CRT.

Its style, like Bush's iconic TR82C radio (described in the September 2013: http://siliconchip.com.au/Issue/2013/September/Best+Of+British%3A+the+Bush+TR82C+Mk.2+transistor+radio), was unmistakably modern. Its sleek grey case, far from being dull, adds an understated finish later seen in many laptop computers.

But styling is only a superficial aspect of the design. The circuitry and physical arrangement of the chassis was far ahead of anything produced at that time. As well as being almost entirely solid-state, all of the circuitry was on PCBs. Mark that; PCBs; plural, not singular. At that time, very few manufacturers anywhere in the world were making a TV set based on PCBs. One of the very few was the American company Admiral but its sets were still all-valve designs.

Apart from its mostly solid-state circuitry, the outstanding feature of this first Sony TV set was that it had a motherboard and three plug-in daughter boards. Decades later, motherboards and daughter boards would become common-place in computers but this was 1959!

I bought this set quite a while ago when I was teaching in Hong Kong. It is the TV8-301W US version. The 301E is the model for Western Europe while the 301T is a special version for Italy.

Circuit description

The block diagram of the circuit is shown in Fig.1 and is quite similar to the previously mentioned Philco Safari set. Indeed, most early solid-state TV sets follow pretty much the same design.

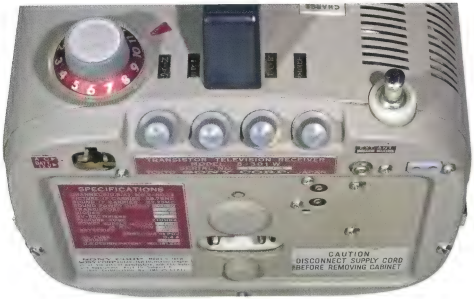
The TV8-301 uses 23 transistors (a mix of PNP and NPN types), 18 semiconductor diodes (19 in the –E and –T models) and three tubes: the two high-voltage rectifiers and the 8-inch CRT. The transistors are all made by Sony but conform to the Japanese "2SA/SB/SC" type numbering, so data and replacements can be determined.

The 13-channel tuner is a turret design though not using the traditional "biscuits" we're familiar with in TV sets manufactured in Australia. Each stage's inductors are mounted on a rotating disc, giving individual inductances for each channel but without the mechanical complexity of the traditional turret tuner. This combines simplicity with the ability to adjust each channel individually.

This TV8-301 is a VHF-only set, UHF transistors not being available at the time of production. Its tuner uses an RF amplifier, converter and separate local oscillator. It has four IF stages, each with neutralisation but operating at only 26.75MHz. All the transistors in this part of the circuit are PNP types, so their emitters are fed from the positive supply and collectors are connected via their transformers to ground.

A separate detector feeds an AGC amplifier for application to the first and second IF stages. And like the Safari, the TV-301 uses simple "envelope" AGC that responds to Average Picture Level (white), rather than to peak signal strength.

The TV8-301 lacks DC coupling in



The adjustment knobs at the back of the set are, from left to right: gain/ contrast, brightness, horizontal hold and vertical hold. The large knob at left is for channel selection and the outer ring is for fine tuning. The unmarked volume control is forward of the channel selector.

The rear of the Sony TV8-301 set shows the AC (USA 117V) and DC (12V) power socket at top left. The large central two pin connector is used to power the set from an external 12V battery. At top right is the whip antenna, with the unbalanced and balanced antenna sockets just below it.

the video amplifier and lacks a DC restorer, both of which are needed to ensure a constant black level.

The video section begins with a conventional diode demodulator, feeding an emitter-follower first video amplifier stage and the sound pickoff trap. The main video amplifier's gain is controlled by a variable resistor in the emitter bypass circuit. This would usually be the contrast control but it's a preset.

The user-adjustable "Gain" control, acting to attenuate the incoming RF signal and control the IF gain, gives the same effect as the usual contrast control. Does this seem familiar? Many earlier valve radios used a similar attenuating/gain design for the their volume controls.

The gain control RF attenuator between the aerial connection and the input to the tuner is combined with a complex variable-bias system applied to the above-mentioned AGC circuit that controls the gain of the first and second vision IF stages

It's usual to allow the RF/IF channel to manage its own gain automatically, and to design it to deliver some 1~3V peak-to-peak either to the contrast control or to an amplifier with its gain subject to the contrast control.

I can only assume that Sony's engineers found their design vulnerable to overloading on strong signals and included the RF attenuator as a solution.

The inherent inductance and capacitance of ordinary volume pots, which vary with frequency, make such an attenuator the exception in RF circuitry. The actual contrast control is a variable-gain affair in the emitter lead of the output transistor, but it's a preset and not accessible to the operator.

The picture tube is a 21cm/8-inch diagonal 210HB4, 90 degree type made by NEC. The larger size helps explain the high accelerator and focus voltages, and video drive, compared to Philco's 2-inch 2EP4.

The video amplifier runs off a 75V DC supply, allowing a full video output of around 60V peak-to-peak. The sound channel begins with the pickoff at 4.5MHz from the first video stage. This sound channel's design, including the Foster-Seeley demodulator, is very similar to that of the Safari but with a higher output of 300mW.

The balance of the circuitry, involving nine transistors, with eight low-voltage and two high-voltage diodes,

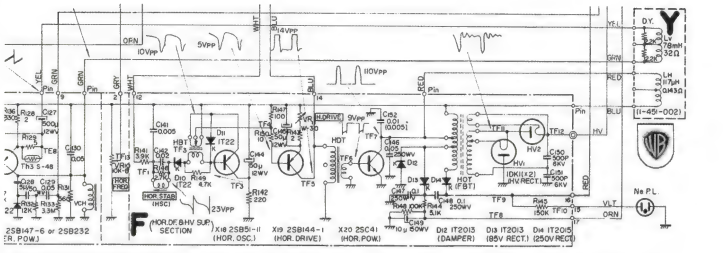


Fig.2: this small section of the complete circuit shows the horizontal output stage (X20) which drives the deflection yoke. The horizontal output transformer (HOT) has a high voltage winding which drives the two thermionic diodes (HV1 & HV2) in a conventional voltage doubler rectifier circuit, to provide the +240V boost voltage for the CRT.

separates the vertical and horizontal synchronising (sync) signals, produces the vertical and horizontal deflection power for the picture tube, and provides medium and high voltage supplies. These transistors are a mix of PNP and NPN types. The TV8-301's vertical deflection circuit is similar to that of the Safari.

The horizontal deflection circuit is also similar to that of the Safari, with the principal differences being that the medium and low-voltage supplies are derived from the horizontal output transformer.

The TV8-301 generates a single medium-voltage +240V boost supply, by rectifying the large flyback pulse generated at the end of each scanned line as the horizontal output transistor is cut off and the deflection transformer/deflection coil magnetic fields collapse. The boost supply connects directly to the CRT as well as feeding +75V to the CRT and the video output stage via dropping resistors.

Since the video output and CRT derive power from the horizontal circuitry (as shown in Fig.2), a set that gives "sound but no picture" is probably (like most TVs) indicating a loss of horizontal deflection.

The main power supply uses a step-down mains transformer feeding 15VAC to a bridge rectifier. After filtering, the set receives +13V for all stages not fed by the horizontal output stage. The set can also run on an external 12V battery, rechargeable from the mains supply, or from a car battery adaptor lead.

The major controls are clustered towards the set's rear, allowing clean cabinet lines that follow the CRT's outline (a similar styling approach was taken with the very popular Pye Pedigree TV set manufactured years later). The only oddity is the un-labelled volume control: it's the tall knob forward of the channel selector.

Servicing and repairs

Unlike the Safari's "board on each side", the TV8-301 uses the above-mentioned motherboard and the three daughter boards sit like horseshoes over the neck of the CRT, giving a tightly packed assembly. This modular approach makes it easy to service. Deflection fault? Just pull the entire deflection board and swap in a good one.

While this simplifies servicing, it does make repairs difficult. Boards will only work when plugged in to the motherboard, so extenders of some kind would be necessary to "sit" the boards up for easy access.

In practice, I found myself removing a suspect board, soldering a lead to a test point, then reinserting the board and testing. It's regrettable that items such as extender boards and other special tools are almost always junked as service centres downsize.

Philip Nelson's online article reports circuit board connector tarnishing, with a distinctive "fingerprint" pattern. I discovered very similar evidence – maybe we can get a forensic investigation team in and track down the culprit some day! Seriously, such deposits can cause long-term corrosion and bring otherwise fine and reliable equipment to a dead stop. Cleaning is easily done with alcohol and a Scotchbrite or similar scourer; definitely not steel wool.

Chassis removal

The main chassis slides "neatly" in to the case. Removal should be straightforward; undo the side and rear securing screws and slide the chassis out. Pry marks on the mating lip are a sure sign that someone hasn't undone all screws before attempting disassembly. Be sure to also unscrew and loosen the underside speaker housing so that the cabinet's speaker slot can expand and ease extraction.

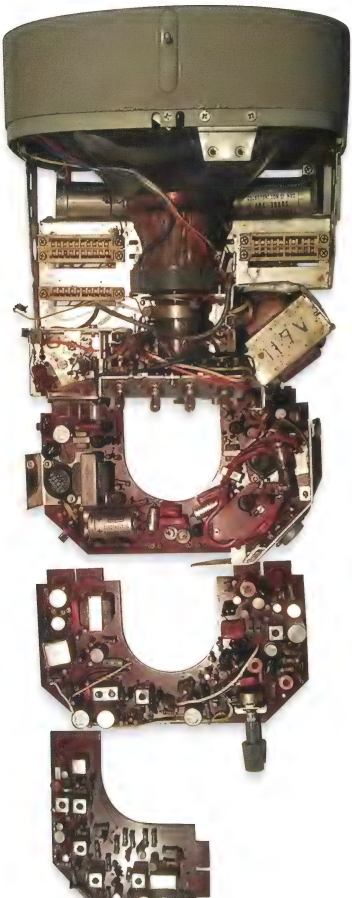
Getting it going

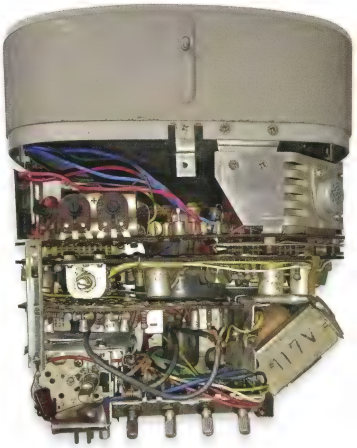
Although I didn't pay much attention at first, my TV8-301's channel indicator light was dead. But so was the screen. It turns out that the channel indicator lamp is a neon running from the 240V DC supply picked off from the horizontal output stage.

So if you've got a TV8-301 with no picture and no channel indicator, don't suspect a dud tube, dead EHT rectifiers, burnt-out horizontal output transformer or other catastrophes. Maybe it's just what I found – the horizontal drive setting is incorrect.

So starting with a dead set, the questions was where to start? Connecting power to the battery input connector gave nothing. On examination, one contact leaf of the Off switch had been bent up away from the sliding contact. Gentle pressure returned it to its tensioned position.

Now, applying power brought up sound but no picture. As well, it began





These two views inside the Sony TV8-301 show the densely packed assembly when the three daughter boards are in place. On the left, the daughter boards have been removed to reveal that they are ordinary phenolic PCBs. Note that the fingers of the daughter boards do not have their contacts gold-plated, so tarnishing of the copper was a problem.

to smell hot. After turning off the power, I found that X20, the 2SC41 horizontal output transistor, was hot to the touch.

A shorted horizontal output transformer or shorts in the high-voltage supplies are the most common causes; the transistor is switched into full saturation for some half of each horizontal line, so a short-circuited load (due to any cause) will see it drawing a lot of collector current.

But it was just getting hot; not cooking. OK, did I have any high-voltage outputs? Yes, the B+ Boost was about 120V, about half the correct value and the EHT measured about 1.5kV, so I didn't have a shorted output transformer. Sigh of relief!

The output transistor's collector waveform was distorted and less than its listed voltage of around 110V peak-to-peak but again, a badly-shorted output circuit would have cut this pulse down to a few tens of volts.

A careful look at the rectifier valves (EHT rectifier) inside the high-voltage screening failed to show any sign of lit filaments, but these are subminatures that don't glow very brightly and the other low outputs probably meant that I wouldn't see them lighting up either. In fact, the EHT rectifier comprises two diodes in a voltage doubler circuit. These are the only thermionic devices in the whole circuit (apart from the CRT). This would have been neces-

W: for U. S. A. E: for Continental Europe (excl. France, Monaco, Italy & OIRT members) T: for Italy

Specifications

Picture Tube :	210HB4
	8 inches, 90-degree Deflection Aluminized Screen, Automatic Control Focus, 8½" in Length
Semi-conductors :	23 Transistors and 18 (19 for 8-301E & T) Diodes
Channel Coverage :	A-2 to A-13 (8-301W), E-2 to E-11 (8-301E), A to H (8-301T)
Scanning System :	Interlaced 525 (625 for 8-301E & T) lines, 30 (25 for 8-301E & T) Frames per second
Sound System :	4.5 (5.5 for 8-301E & T) Mc Intercarrier System
Maximum Sensitivity :	Approx. 30 μV at Antenna Input for All Channels
With Built-in Antenna :	Receives up to 62 miles in flat terrain
With External Antenna :	Receives up to 93 miles in flat terrain
Intermediate Frequencies :	Video 26.75 Mc Sound 22.25 Mc (21.25 Mc for 8-301E & T)
Video Band Width :	3.0 Mc 3 dB (3.5 Mc 3 dB for 8-301E & T)
Resolution :	Vertical 400 Lines Horizontal 250 Lines
Audio Output :	300 Milliwatts with 10% Distortion
External Antenna Input :	300Ω balanced, 75Ω unbalanced
Speaker :	4" × 2½" PM Dynamic
Earphone Jacks :	2
Power Requirements :	DC 12 Volts, 13 Watts AC 50 60 cps 117 V (220 V for 8-301E & T)
	19 Watts Car Battery provided 12 Volts
Batteries :	12 Volts (Two Units of 6 volts) 3 Ampere Hours, Lead Acid, Leakproof
Life of Batteries :	More than 100 recharging cycles under proper maintenance
Recharging Hours :	7 to 10 Hours with Built-in Charger
Dimensions :	Main Unit 8⅛"(W) × 7"(H) × 9"(D)
	Battery Case 6⅛"(W) × 3⅞"(H) × 2"(D)
Weight :	Main Unit 13 pounds
	Battery 4 pounds

SONY®

SERVICING GUIDE

Above: this part of the servicing guide for the Sony TV8-301 shows the general specifications of the set for various regions in Europe and the US.

sary because semiconductor diodes at the time did not yet have sufficiently high PIV ratings.

Lifting the EHT doubler's connection had no effect on the B+ boost. Reconnecting the EHT and removing the B+ boost had no useful effect either. So what about the drive to the horizontal output transistor? The transistor needs enough drive to force it into saturation, so low drive will give low deflection and, more importantly, low output from supplies run off the output transformer.

Careful checking showed that the horizontal output drive was too high. Odd. A simple tweak brought the output stage's drive voltage back to its correct value of around 9V peak-to-peak. This took the transistor out of overdrive (which I assume was being rectified at the base and putting it close to cut-off for too long).

With the drive voltage fixed, the set came to life. I also noticed a distinctive glow from the two EHT rectifier filaments. And the channel indicator came on.

After that, there was not much more to do, really. Check all other voltages, adjust the horizontal and vertical hold presets to run at 15625Hz and 50Hz for testing here in Australia, and that was about all.

The set's original 4.5MHz FM sound channel works just fine, since my benchtop RF "beamer" has had its sound channel dropped down from 5.5MHz (Australian PAL) to the NTSC value of 4.5MHz. This was described in the previous article on the Philco Safari.

Using it

It looks, feels and carries like a portable telly should. It sits easily on a table or bench, without the Safari's top-heavy appearance that suggests blowing over in the mildest of breezes. Since the CRT faceplate "fronts" the set, it is quite subject to screen reflections.

The viewing hood does help with overhead illumination but even more than with the Safari, careful placement helps in viewing.

The 300mW audio output is fine for indoors and adequate for outside use.

And how good is it? Pretty good, actually. It's the first TV set I've worked on that specifies an RF sensitivity. Sony claim "30 microvolts". In practice, this is the minimum for a usable picture but it does at least help in determining whether the set's gain and sensitivity are up to spec.

At eight inches (200mm/20cm) diagonal the screen is large enough for viewing by two or three people. And like Sony's later revolutionary "Walkman" (first generation), there are two earphone sockets for "buddy" listening.

Would I buy another? Maybe. They do appear from time to time, though I've not seen the –E version, which would work directly on any CCIR/PAL RF converter, with its 5.5MHz sound IF. Perhaps one for the shed, one for the verandah?

At least two different circuit diagrams exist. One shows an incorrect waveform (about 110V peak-to-peak) at the collector of X19, the horizontal driver transistor. This should be the waveform for the X20 horizontal output collector, and is correct in the diagram available from www.radiomuseum.org

Further reading

A complete repair article appears on Philip Nelson's fine website, along with many other restoration articles at: www.antiqueradio.org/Sony8-301WTelevision.htm

I must thank Ernst Erb for the schematic, from www.radiomuseum.org

A complete description of horizontal output stages appears at: www.earlytelevision.org/damper.html SC

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Solar MPPT Charger question

I have started building your Solar MPPT Charger & Lighting Controller from the February and March 2016 issues.

There's something I don't understand in the circuit description. On page 32 of the February issue, you state that the gain of op amp IC2b is -45 however the op amp's negative rail is connected to ground (0V), so how can the op amp provide a negative output?

Maybe it's not necessary to measure the panel current, since the firmware can adjust the PWM duty-cycle to maintain the constant MPPT voltage. Is that how it works? (M. C., via email)

- The input voltage to op amp IC2b is negative, due to the direction that current flows through the 0.01Ω shunt resistor. So with a negative gain, the output of the op amp is positive (ie, above 0V) and hence no negative supply voltage is required.

Note that while the voltage across the shunt is negative, because of the divider between it and the output of IC2b, the voltage at pin 6 does not actually go negative; the op amp feedback maintains that pin voltage at 0V.

The current does need to be measured so that the power can be calculated. The circuit is trying to find the solar panel voltage at which maximum power is achieved and thus power must be measured. It is calculated as current multiplied by voltage. It is not sufficient just to measure voltage to determine the maximum power transfer from the solar panel as this will vary depending on panel type, temperature, insolation and so on.

Using alternate mode for Ultrasonic Cleaner

I have built your Ultrasonic Cleaner (from the August 2010 issue) from an Altronics kit (K6021). While the "normal" mode works fine, I cannot get the unit to switch to the "alternate" mode. Holding the start button down while applying power does not even power the unit up (both LEDs are off and no sound produced). Any suggestions? (R. Z., via email)

- Check that diode D4 is oriented correctly. If it is incorrectly oriented, this would short the 5V supply when the start button is pressed. However, the fact that the power LED does not light suggests that the main 12V supply is off when the start button is pressed during power up. That's because the power LED is driven via the 12V supply. Check whether 12V is present at this time.

Is Stationmaster safe for locomotive motors?

I have some questions about the Stationmaster PWM train controller from the March 2017 issue.

I built a PWM train controller, possibly ten years ago. It was quite a big unit with built-in transformer and walk-around throttle.

I used it successfully with HO and N gauge layouts and found it to be "realistic". I then built a Z gauge layout and connected the same PWM controller to it, not using the walk-around throttle because of the layout size. The track voltage was limited to 9V by means of a resistor in series with the speed pot, if I remember correctly.

I run a steam loco and noticed a rather loud "rattling" sound, especially at low speed and within a short time (1-2 minutes), the loco stopped dead on its track. It was very hot to the touch. The motor had burned out. It had run well with a normal (Märklin) transformer for several hours before.

This new design appeals because of its small size but will a similar thing happen again and why? Is it because small motors have no flywheel, hence the rattling noise? Have you heard of similar problems with Z gauge or other small motors?

By the way, CON2 on the Stationmaster circuit diagram appears to be drawn with all its terminals shorted. Also, LED4 is labelled as LED5 in the circuit diagram on page 36. (H. M., Bowral, NSW)

- The Stationmaster will not cause rattling because it runs at a much higher PWM frequency of around 8-9.5kHz. However, that might be

Ultrasonic Anti-fouling wiring and testing

I have finished putting together the Jaycar KC-5498 kit for the Ultrasonic Anti-fouling (SILICON CHIP, September & November 2010) but there is no instruction as to which colour wire goes where on the transducer out from the circuit board.

Also, how do I adjust it? There are no testing steps in the instructions. (G. D., via email)

- The wires to the transducer can be any colour and it does not matter which way they connect to the terminals. So long as you connect each of the two transducer wires to the two separate terminal entries, it should work.

The only adjustment is for the 5V rail and this is described in the text under the section entitled Adjustment.

The ultrasonic bursts are generated by software within IC2 and there is no adjustment required. If you want to test if the transducer is being driven, place the transducer onto a hard surface and power up the Ultrasonic Anti-fouling unit.

The transducer should move slightly every few seconds as the drive signals pass through the transducer's resonance frequency.

Alternatively, set a portable AM radio between stations; you should then be able to hear the hash from the driving circuitry when it's placed near the transducer wiring.

Utilising solar power when the grid is down

Being impressed with the reliability of solar electricity and the generous government rebates available several years ago, I (like many others) had a solar system fitted to my house. It has worked without any issues and has enabled me to save a moderate amount of money since it was commissioned.

I would like to know if anyone has come up with a simple 12V charger that could be utilised by the HV solar DC supply that normally goes to the inverter. By law, when the grid supply fails, so too does the inverter's output and electrical generation from the solar system. I see this as a lost opportunity.

By simply connecting the solar plugs (that normally feed the solar inverter) into a charger that can supply 12V to charge a backup battery, this could provide enough power to run a 12V-to-230V inverter to keep your refrigerator and freezer running through the day.

If there was enough battery backup, the available capacity could be increased through the night but there is a trade-off with the cost of maintaining a lot of batteries.

By disconnecting the mains and solar inverter from the solar panels, a well-designed backup system should be possible to employ, maintaining safety. An extension lead could supply 230VAC to your fridge and freezer from the inverter.

I must stress that the backup system must not be connected to the house mains in any way as this is not only dangerous and illegal but there is no isolation from the grid.

I have thought about fitting a solar array changeover switch to make a fully automatic system but I would be interested to hear if you know of a commercial solution as suggested. With the uncertainty and reliability in the electricity grid of recent times, I believe these are options that we need to look into, to help ourselves for emergency situations. (C. B., Geelong, Vic)

- That's an interesting suggestion but it is important to note that the solar panel supply to your grid-feed inverter will typically be around 360V DC so any step-down 12V charger is not likely to be a simple or inexpensive device.

One possibility which might be workable would be to use a 230VAC to 12V DC switchmode power supply or high power battery charger.

Given that the input to these switchmode power supplies is a bridge rectifier, it should be able to accept the high voltage DC from the solar panels.

Such a switchmode 12V supply could probably be then used to directly drive a 12V to 230VAC inverter, possibly with a 12V lead acid battery also connected across the 12V DC rail.

We must emphasise that we have not done any work on this concept and that any modifications to the connections between the solar panels and your existing grid-tied inverter may contravene the regulations for these installations.

audible from the locomotive, depending on its mechanism. If you want to try changing the frequency, you can do so by increasing the value of the 10nF capacitor between pins 6 and 7 of IC1.

Thanks for bringing the circuit errors to our attention. We will publish errata and correct the diagram in the online version of the magazine.

Faulty trimpot in Jacob's Ladder

I just finished my second Jacob's Ladder kit (April 2007), and for some reason cannot get the same result as my first; VR1 seems to have no effect. I can get the spark to happen with VR2, but get no change when turning VR1. My first kit was great and I am unsure what would cause this. (D., by email)

- You should be able to get a voltage change by adjusting VR1. So with a multimeter connected between pin 18 and 0V (GND) the voltage should vary between 0V and 5V as VR1 is adjusted. If this does not happen, there may be a fault with the trimpot (VR1) where the wiper is open circuit. Alternatively, there could be a dry joint connection to one of the trimpot terminals or to pin 18 of IC1. Check also that pin 18 is not bent up under the IC so it does not make contact with the IC socket.

Multiple pool pump failures

We have a small above-ground swimming pool complete with pump, purchased for Christmas. After only four weeks, the pump failed; there was a bulge in one side of the area covered in epoxy resin. The pump is totally sealed with the mains lead going in through the resin; it is similar to a submersible pump. It was replaced under warranty.

A week later, after only four hours of use, the replacement pump was tripping off the safety switch and again there was bulge in the area covered by the resin. Contacting the supplier, I was advised there must be a fault with my electricity service for two pumps to do this as they had no other complaints. I was initially asked to use a 15A extension lead as there could be a voltage drop in our 10A lead.

The pump is only rated at 16W and our lead is 6m long; this was suggested by the owner who tells me he was an electrician.

I have enjoyed electronics for the last 55 years and although not an electrician, I feel I know enough that this is not the cause of the failure. I have tested the pump with my multimeter. It has a three-pin plug terminating 6mm flex which I believe to be three-core. There is a dead short between all three pins, suggesting the windings are touching the coil former which could have the earth wire attached.

I believe the rotor is magnetically driven through the plastic for safety. Could my mains supply be at fault? Perhaps the voltage is too high? What else could cause this sort of failure – a mains surge? Overheating? Blocked pump? (G. H., Littlehampton, SA)

- Why would a pump rated at 16W need a 10A or 15A extension lead? Surely the pump uses much more power than that. Even so, if a submersible pump or any pump trips your safety switch, the pump has failed. Simple. It has nothing to do with your mains supply. You can check your mains supply

Using LED Strobe circuit to fire high voltage coil

I am experimenting with an ignition coil to generate a high voltage but am not sure what frequency or power to drive it at. I am considering using the August 2008 LED Strobe circuit as the coil driver. It provides an accurate, adjustable switching frequency.

But instead of the output driving a BC337 transistor, I am planning to drive the input of an optocoupler (4N28) via a 1kΩ resistor, to isolate the strobe circuit from the coil.

I would then use the output from the optocoupler to drive a power Mosfet (IRF540) which switches current through the coil. I would fit a diode across the coil inputs to protect the Mosfet and a resistor in series with coil to limit the current.

I'm not sure whether I can use the strobe power supply to also power the coil. Any advice would be appreciated. (C. K., Parkhurst, Qld)

● Whether you use the same supply or a different one for the LED strobe circuit and coil really depends on whether the supply voltage for each is the same and whether the coil supply will drop under load.

You could test your circuitry with separate supplies as you have already catered for this by using an optocoupler for circuitry isolation. Then once you have established that your circuitry works, try to use the same supply for both, assuming the voltages are the same.

You may need to isolate the LED strobe circuit supply from the coil with a low-value resistor or a diode and provide extra filtering with a larger electrolytic supply capacitor, to prevent noise from the coil upsetting the driving circuitry.

with your multimeter but we would be surprised if it was particularly high.

The only situation in which your mains supply might be particularly high is if you live in an area where there are lots of houses with solar panel installations; that can lead to high local mains supply; perhaps above 250VAC.

We're assuming that if it is indeed a submersible pump, it has been operated while submersed in water; submersible pumps often rely on the water for cooling and will quickly overheat and fail if run dry for more than a short time.

Assuming you have been using it correctly, ask the supplier to replace your pump or give you a full refund. Or threaten to go to the consumer affairs /fair trading regulator in your state or territory and show them the pump.

Capacitor quality and "audiophile" rip-offs

I am about to start the renovation of a Playmaster 10 watt Stereo Amplifier (EL84 version published in Radio, TV & Hobbies, December 1959) together with a Playmaster 10 Stereo Pre-amplifier (Published in RTV&H, May 1960).

Both units utilise electrolytic capacitors, polyester capacitors ("mustards"), polystyrene and silver mica capacitors – the majority, with the exception of the silver mica, need replacing.

My question relates to the choice of replacements for the polyester and polystyrene capacitors. It seems that certain polyester capacitors have almost a cult following, eg, "mustards", "tropical fish" etc. Is there really a difference between reputable brands of polyester film capacitors or is this akin to the perceived difference in speaker and power cables?

I was recently offered a mains cable for my Luxman 505uX for $1300 – Luxman themselves seem to think that a conventional IEC cable ($8) quite sufficient for their amplifier!

In my last renovation of Mullard 5-10s (published in SILICON CHIP, October 2014), I used Cornell Dubilier polyester film and the end result was fine, with low noise and distortion. I notice that in your Currawong amplifier, you use polyester film capacitors by Suntan and as far as I know these are considered to be a generic, good value product.

So, assuming I am to replace all the "mustards" in both units (these have a 1960 third quarter date code), is it really necessary to pay a fortune for NOS or modern copies of the "mustards" when I can purchase modern metalised polyester film capacitors from reputable manufacturers for a fraction of the cost? (M. F., Mount Eliza, Vic)

● In spite of the age of these Playmaster projects, we would be surprised if the plastic film capacitors, especially the polystyrene types, need replacing.

If you do need to replace these capacitors, any general purpose metallised polyester, polypropylene or polcarbonate capacitors with adequate voltage ratings will be quite suitable. Do not pay high prices for NOS (new old stock) components if modern components can do the job.

However, it is quite likely that you will have to replace many, if not all of the electrolytic capacitors and possibly some of the carbon resistors which may have drifted high in value.

The manufacturers of Luxman amplifiers know far more about audio performance than the promoters of esoteric power leads, speaker cables, interconnects and whatever other "fabled" products are out there for gullible audio enthusiasts. The standard IEC power cable will work just fine.

If you want to know more, we suggest you take a look at Douglas Self's book Small Signal Audio Design (reviewed in the May 2011 issue), which goes into quite some detail about the difference in performance between different types of capacitors, resistors and so on.

In short, he finds that there is some difference in performance between various types of plastic film capacitors, most of them are only evident in equipment which already has a distortion level well below 0.001%. It's only in well-designed modern equipment with vanishingly low THD+N levels where, for example, a polypropylene capacitor will give a measureable improvement compared to a bog-standard polyester type.

Courtesy Light Delay not wired correctly

I purchased a Courtesy Light Delay kit (KC5392) from Jaycar in Hallam, Victoria last Friday, then assembled the kit on the same afternoon.

When done, I tested it with a 12V battery rather than dismantle the car courtesy light and install it first. I wanted to make sure it worked off the

Run 12/24V Motor Speed Controller from 18V

I have a project to motorise a billy cart with a 12V DC cordless drill motor and I want to use the 20A 12/24V DC Motor Speed Controller Mk.2 from your June 2011 issue.

I have a number of 18V tools at home with their respective batteries and chargers and I was wondering if there was any way of using the speed controller with an 18V supply to run a 12V motor. (D. H., Maleny, Qld)

● You can run a 12V DC motor from 18V provided that you set the upper speed (with VR1) to provide up to an average of 12V. Do not run it up to full speed where the average voltage will be 18V or you might burn out the motor.

You can increase the value of the 1kΩ resistor that's in series with VR1 so that the motor voltage is restricted to 12V with VR1 fully clockwise.

Try a 3.3kΩ resistor. The low-voltage cut-out should be set to suit the battery voltage. For an 18V supply, use a multiplication factor of 0.317.

car, a Nissan Pathfinder with a negative chassis.

When connected across a 12V light globe wired to a lead-acid battery, it does not work as expected.

The light comes on only when the negative wire from the globe touches negative on the battery, but when the wire is removed, the light doesn't remain on.

However, if the wire is left on the negative pole of the battery, the light stays on until time set by the pot is over then it dims and goes off. This shows that there is something wrong with this kit. ("valiantman", via email)

● The problem is that you are not wiring the Courtesy Lights Delay correctly. The door switch connections on the unit shown as D+ and D- are to connect across the door switch. In your diagram, you show that you have connected the door switch connections between battery positive and the lamp.

Three horsepower motor drive wanted

A good while ago (in April and May 2012), you described an Induction Motor Speed Controller that could drive a delta-wired 3-phase motor from a single phase supply. I don't think you've done anything similar since.

My problem is slightly different: I have an old 3-phase motor wired in a Y or star configuration. Importantly, it only exposes one end of each of the motor's coils at its connection point. The common connection point is (presumably) buried deep in the motor and I am somewhat unwilling to pull the whole thing apart to see if I can find this common connection point.

Can a Y-configured 3-phase motor also be driven from a single phase input? Have you considered describing a suitable device? My motor is rated at a nominal 3 HP (ie, about 2.25kW) so I'd really like something which can handle that much power if possible. Finally, I'd be using it in my garage, where I have a 15A outlet, if this is needed. (G. B., via email)

● There are three problems with your proposal. First, you cannot make a three-phase motor run with only one of its phases energised. At the very least, you would need two phases energised with the second phase coupled via a capacitor to produce a rotating magnetic field (similar to a capacitor-run single phase motor).

However, even if you did cobble some sort of split-phase arrangement from a single phase, you would not have enough voltage to drive a three-phase motor, which normally runs from 415VAC.

Second, we would not recommend any attempt to access the common connection for an old Y-connected motor. Any disturbance of the windings or connections is likely to lead to subsequent failure.

Third, our Induction Motor Speed Controller has a output power rating

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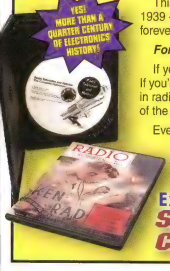

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Source code for 12V to 230VAC Sinewave Inverter

Could you please send me a copy of the source code for the variable speed drive in April 2012's edition.

I would like to learn more about PIC assembly language and also want to build a 12V DC to 230VAC pure sinewave inverter with a similar sort of circuit.

Do these circuits usually feed a 12V PWM sinewave signal through a transformer primary to get the 230VAC or do they just create a 230VAC sinewave with a higher voltage that has already been stepped up and rectified?

Any help would be greatly appreciated. (R. B., via email)

● It has not been our policy to provide the source code for the Induction Motor Speed Controller project since alterations to it are extremely likely to cause catastrophic failure in the inverter circuitry, as we know from our own experience in developing that project.

In any case, what we have done in that speed controller is not directly applicable to what would be needed for a 12V to 230VAC sinewave inverter.

As far as we know, any practical design capable of reasonable power and efficiency uses a high frequency boost converter to step up to about 360V DC or more and then uses a PWM bridge circuit to synthesise a 50Hz (or 60Hz) sinewave modulated waveform (note that word "synthesise").

It is then necessary to have LC circuitry to remove the high frequency switching artefacts to produce a clean sinewave.

If you want to know how the Induction Motor Speed Controller works, we suggest you closely read the explanation in the April 2012 article and particularly the section which mentions a "squashed" sinewave.

Note that the April 2012 design is essentially a 3-phase variable frequency variable voltage speed controller and it is only intended for use with single phase and 3-phase induction motors. Its output device is a 3-phase bridge with six IGBTs.

The main functions of such a variable speed drive are not needed for a single-phase sinewave inverter.

However, since 3-phase IGBT bridges are now available quite cheaply, it might well be practical approach to use a 3-phase IGBT bridge in a sinewave inverter.

If you want to read a comprehensive description on how a sinewave inverter (with boost converter) works, have a look at our 2kW 24V DC to 240VAC inverter from the October 1992 issue.

This was published over five months from October 1992 to February 1993 but you only need to read the description in the first issue.

By the way, these days a high-power DIY sinewave inverter is not a practical proposition since commercial units are much cheaper and definitely more reliable.

of 1.5kW or 2 HP. That figure is limited by the driving circuitry, its efficiency and the 10A limit of a normal 230VAC 10A GPO (ie, standard domestic power point). Even with a 15A GPO, there is no way that the power output can be increased to reliably drive a 3HP motor which would still need to be wired in delta configuration.

24VAC to 24V DC power supply wanted

I was wondering if Silicon Chip could assist me with sourcing or constructing a power supply. It needs to operate with a 24VAC input, 24V DC output and rated to at least 100VA.

I realise that one option is to simply put a bridge rectifier on the 24VAC supply and then connect it to a standard DC/DC converter, however, I believe that this may cause some problems with regard to the correct operation of the DC/DC converter. I have searched far and wide for an off-the-shelf unit which can fulfil my requirements, all to no avail. (R. P., Burnett Heads, Qld)

● If you use a 10A bridge rectifier such as the BR106 and two 4700μF 50V capacitors for filtering (to give ~4V ripple at 4A), you will have about 33V DC unloaded. This could be regulated down to 24V DC with an LM338 regulator. A 1.1°C-rated fan-type heatsink with fan cooling will be necessary to keep the regulator cool. The NDS-packaged device should be used. Note though that while this will do the job, it is an inefficient solution.

You could replace the LM338 with a DC/DC converter as you have suggested and it should have no problem running from this supply as long as it's rated to operate off 30-36V when producing 24V DC. However note that DC/DC converters can generate a fair amount of high-frequency hash, both radiated and in their DC output; whether this matters or not depends on your application.

Alternatively, if you can use 230VAC mains instead of 24VAC, a switchmode supply such as the Jaycar MP-3189 (24V at 6.5A) would be suitable.

DIY Bluetooth receiver wanted

Has Silicon Chip ever done a Bluetooth receiver that works with iPhone/iPad/other smart units? Perhaps there is a project possibility for enabling the iPhone to drive a good set of speakers with Bluetooth connectivity? (J. K., Castlecrag, NSW)

● Commercial Bluetooth audio dongles are so cheap now (just a few dollars) that there isn't much point even trying to build one. We did purchase a Bluetooth audio module but the data on it was woefully inadequate and we couldn't get it to work reliably.

Problem with Garage Parking Assistant

I've built the Micromite Garage Parking Assistant from the March 2016 issue but it doesn't seem very stable. The coloured screens and number display are changing continually even when a fixed object is placed in front of the sensor. Any suggestions to solve this would be appreciated. (G. O., Ringwood, Vic)

● The first thing that you should check is your 5V power supply. A number of readers have reported erratic operation of the distance sensor when using a USB charger for the power supply. If possible, it would be

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worth testing the complete backpack/sensor using a lab power supply or by using alternative USB supplies such as a computer's USB outlet.

Fixed frequency Ultrasonic Cleaner

Could you please put me in touch someone experienced in writing the source code for PICs. I am especially interested in the code used for Ultrasonic Cleaner project (August 2010). I would like to discuss whether there is a simple way of modifying source code to generate a single frequency output from the transducer. I would appreciate very much your help and support. (M. T., Vic)

- We do have a version that runs at either 28kHz continuously or 40kHz continuously. The frequency is changed from one to the other by holding the start switch pressed when the ultrasonic cleaner is powered up. The ASM and HEX files are available upon request.

If you are after different frequencies, you can compare the values for each frequency shown in the lookup table that is labelled SWEEP1 and SWEEP2 with those used in the original assembler file "ultrasonic cleaner.asm", which is available for download from our website. See www.siliconchip.com.au/Shop/?article=244 SC

Next Month in Silicon Chip

Getting Started with the Micromite, Part Three

In the third part of Geoff Graham's MMBasic programming tutorial, he covers some more advanced subjects such as data types, arrays and drawing text on an LCD screen.

Industrial Robots

Dr David Maddison takes an in-depth look at the history of industrial robots, which perform many important tasks with a speed and precision that humans can't match.

How to use LTspice to simulate circuits

The first in a series of easy-to-follow, step-by-step tutorials on using the free LTspice Windows circuit simulation software from Linear Technology.

Ultrasonic Anti-fouling for Boats, Mk2

This revised anti-fouling unit drives two transducers, has soft-start to prevent nuisance fuse blowing, simplified set-up and neon indicators to show output activity.

1000:1 6GHz+ Prescaler

Allows a standard frequency counter to be used for signals up to 6GHz and beyond. Has a selectable division ratio for better resolution with intermediate frequencies.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The May 2017 issue is due on sale in newsagents by Thursday April 27th. Expect postal delivery of subscription copies in Australia between April 27th and May 12th.

Notes & Errata

Pool Lap Counter, March 2017: on the circuit diagram two 1kΩ resistors are missing between the bases of Q4 & 6 and the collectors of Q3 & 5 respectively. Both are shown correctly on the PCB and are listed in the parts list.

Stationmaster, March 2017: on page 36, Fig.2, LED5 is mistakenly listed twice, LED4 is the one closest to CON3. Also, CON2 is shown with all its connections shorted on Fig.2, the PCB has the correct connections made.

Squash and Ping-Pong, Circuit Notebook, February 2017: Trimpot VR1 should be connected directly to the +5V rail rather than junction of the reset switch and 100nF capacitor. If this is not done, the speed of the ball cannot be properly adjusted.

Voltage/Current Reference with Touchscreen, October & December 2016: in the overlay diagram (Fig.3) on page 66 of the December 2016 issue, a 10nF capacitor is shown below and to the right of IC3 (near the centre at the top of the board). This should be 100nF instead, to reduce noise in the output. It is shown correctly in the circuit diagram in the October issue, between pins 1 and 2 of IC5a, and listed correctly in the parts list. The PCB correctly shows this as 100nF on the silkscreen.

SemTest, February, March & May 2012: in the parts list on page 86 in May 2012, SCR1 is incorrectly listed as a TYN812 semiconductor, where it should be a TYN816.

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